S.I.A

REPORT

OF THE

SIXTY-THIRD MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

NOTTINGHAM IN SEPTEMBER 1893.

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
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[*An asterisk * indicates that the title only is given. The mark † indicates the same, but a reference is given to the journal or newspaper where it is published* in extenso.]

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In 1889 (*Newcastle*) *Report.*

Page 28. In equation (2) for $+(x^2+n^2)u$, read $-(x^2+n^2)u$.

In 1893 (*Nottingham*) *Report.*

Page 308, fig. 10. The Scale should be transferred to fig. 4, p. 295.

OBJECTS AND RULES

OF

THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive

gratuitously the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis;* but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members *who have not intermitted* their Annual Subscription.
2. *At reduced or Members' Price*, viz., two-thirds of the Publication Price. —Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]
3. Members may purchase (for the purpose of completing their sets) any of the volumes of the Reports of the Association up to 1874, *of which more than* 15 *copies remain*, at 2*s*. 6*d*. per volume.[1]

Application to be made at the Office of the Association.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

[1] A few complete sets, 1831 to 1874, are on sale, at £10 the set.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons :—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.[1]

1. Delegates nominated by the Corresponding Societies under the conditions hereinafter explained. *Claims under this Rule to be sent to the Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

Organising Sectional Committees.[2]

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organising Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections,[3] and of preparing Reports

[1] Revised by the General Committee, 1884.

[2] Passed by the General Committee, Edinburgh, 1871.

[3] *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be read, are now as far as possible determined by Organising Committees for the several Sections *before the beginning of the Meeting.* It has therefore become

thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organising Sectional Committees.[1]

An Organising Committee may also hold such preliminary meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to nominate the first members of the Sectional Committee, if they shall consider it expedient to do so, and to settle the terms of their report to the Sectional Committee, after which their functions as an Organising Committee shall cease.[2]

Constitution of the Sectional Committees.[3]

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday, and on the following Thursday, Friday, Saturday,[4] Monday, and Tuesday, for the objects stated in the Rules of the Association, and specified below. The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and the Sectional Committee.

The business is to be conducted in the following manner:—

1. The President shall call on the Secretary to read the minutes of the previous Meeting of the Committee.
2. No paper shall be read until it has been formally accepted by the

necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each author should prepare an Abstract of his Memoir of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before........................., addressed to the General Secretaries, at the office of the Association. 'For Section.........' If it should be inconvenient to the Author that his paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note. Authors who send in their MSS. three complete weeks before the Meeting, and whose papers are accepted, will be furnished, before the Meeting, with printed copies of their Reports and abstracts. No Report, Paper, or Abstract can be inserted in the Annual Volume unless it is handed either to the Recorder of the Section or to the Assistant General Secretary *before the conclusion of the Meeting.*

[1] Sheffield, 1879. [2] Swansea, 1880. [3] Edinburgh, 1871.

[4] The meeting on Saturday is optional, Southport, 1883.

Committee of the Section, and entered on the minutes accordingly.

3. Papers which have been reported on unfavourably by the Organising Committees shall not be brought before the Sectional Committees.[1]

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Report. He will next proceed to read the Report of the Organising Committee.[2] The list of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printer, who is charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section (generally the Recorder) should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings,* to the Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xxvii), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association, and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and*

[1] These rules were adopted by the General Committee, Plymouth, 1877.

[2] This and the following sentence were added by the General Committee, Edinburgh, 1871.

one of them appointed to act as Chairman, who shall have notified personally or in writing his willingness to accept the office, the Chairman to have the responsibility of receiving and disbursing the grant (if any has been made) and securing the presentation of the Report in due time; and, further, it is expedient that one of the members should be appointed to act as Secretary, for ensuring attention to business.

That it is desirable that the number of Members appointed to serve on a Committee should be as small as is consistent with its efficient working.

That a tabular list of the Committees appointed on the recommendation of each Section should be sent each year to the Recorders of the several Sections, to enable them to fill in the statement whether the several Committees appointed on the recommendation of their respective Sections had presented their reports.

That on the proposal to recommend the appointment of a Committee for a special object of science having been adopted by the Sectional Committee, the number of Members of such Committee be then fixed, but that the Members to serve on such Committee be nominated and selected by the Sectional Committee at a subsequent meeting.[1]

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

The Committees of the Sections shall ascertain whether a Report has been made by every Committee appointed at the previous Meeting to whom a sum of money has been granted, and shall report to the Committee of Recommendations in every case where no such Report has been received.[2]

Notices regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in science are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Chairman of a Committee to whom a money grant has been made must forward to the General Officers, before July 1, a statement of the sums which have been expended, with vouchers, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one Meeting of the Association expire on June 30 following; nor is the Treasurer authorised, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General

[1] Revised by the General Committee, Bath, 1888.
[2] Passed by the General Committee at Sheffield, 1879.

Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Chairman is the only person entitled to call on the Treasurer, Professor A. W. Rücker, F.R.S., Burlington House, London, W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation shortly before the meeting commences. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At the time appointed the Chair will be taken,[1] and the reading of communications, in the order previously made public commenced.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1. To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.
2. To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's, or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Secretary.
3. Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed in the programme, p. 1.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

[1] The Organising Committee of a Section is empowered to arrange the hours of meeting of the Section and Sectional Committee. Passed by the General Committee at Edinburgh, 1892.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

Presidents of the Association in former years are *ex officio* members of the Committee of Recommendations.[1]

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

All proposals for establishing new Sections, or altering the titles of Sections, or for any other change in the constitutional forms and fundamental rules of the Association, shall be referred to the Committee of Recommendations for a report.[2]

If the President of a Section is unable to attend a meeting of the Committee of Recommendations, the Sectional Committee shall be authorised to appoint a Vice-President, or, failing a Vice-President, some other member of the Committee, to attend in his place, due notice of the appointment being sent to the Assistant General Secretary.[3]

Corresponding Societies.[4]

1. Any Society is eligible to be placed on the List of Corresponding Societies of the Association which undertakes local scientific investigations, and publishes notices of the results.

2. Application may be made by any Society to be placed on the List of Corresponding Societies. Applications must be addressed to the Secretary on or before the 1st of June preceding the Annual Meeting at which it is intended they should be considered, and must be accompanied by specimens of the publications of the results of the local scientific investigations recently undertaken by the Society.

3. A Corresponding Societies Committee shall be annually nominated by the Council and appointed by the General Committee for the purpose of considering these applications, as well as for that of keeping themselves generally informed of the annual work of the Corresponding Societies, and of superintending the preparation of a list of the papers published by them. This Committee shall make an annual report to the General Committee, and shall suggest such additions or changes in the List of Corresponding Societies as they may think desirable.

4. Every Corresponding Society shall return each year, on or before the 1st of June, to the Secretary of the Association, a schedule, properly filled up, which will be issued by the Secretary of the Association, and which will contain a request for such particulars with regard to the Society as may be required for the information of the Corresponding Societies Committee.

5. There shall be inserted in the Annual Report of the Association

[1] Passed by the General Committee at Newcastle, 1863.
[2] Passed by the General Committee at Birmingham, 1865.
[3] Passed by the General Committee at Leeds, 1890.
[4] Passed by the General Committee, 1884.

a list, in an abbreviated form, of the papers published by the Corresponding Societies during the past twelve months which contain the results of the local scientific work conducted by them; those papers only being included which refer to subjects coming under the cognisance of one or other of the various Sections of the Association.

6. A Corresponding Society shall have the right to nominate any one of its members, who is also a Member of the Association, as its delegate to the Annual Meeting of the Association, who shall be for the time a Member of the General Committee.

Conference of Delegates of Corresponding Societies.

7. The Conference of Delegates of Corresponding Societies is empowered to send recommendations to the Committee of Recommendations for their consideration, and for report to the General Committee.

8. The Delegates of the various Corresponding Societies shall constitute a Conference, of which the Chairman, Vice-Chairmen, and Secretaries shall be annually nominated by the Council, and appointed by the General Committee, and of which the members of the Corresponding Societies Committee shall be *ex officio* members.

9. The Conference of Delegates shall be summoned by the Secretaries to hold one or more meetings during each Annual Meeting of the Association, and shall be empowered to invite any Member or Associate to take part in the meetings.

10. The Secretaries of each Section shall be instructed to transmit to the Secretaries of the Conference of Delegates copies of any recommendations forwarded by the Presidents of Sections to the Committee of Recommendations bearing upon matters in which the co-operation of Corresponding Societies is desired; and the Secretaries of the Conference of Delegates shall invite the authors of these recommendations to attend the meetings of the Conference and give verbal explanations of their objects and of the precise way in which they would desire to have them carried into effect.

11. It will be the duty of the Delegates to make themselves familiar with the purport of the several recommendations brought before the Conference, in order that they and others who take part in the meetings may be able to bring those recommendations clearly and favourably before their respective Societies. The Conference may also discuss propositions bearing on the promotion of more systematic observation and plans of operation, and of greater uniformity in the mode of publishing results.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

(1) The Council shall consist of [1]

1. The Trustees.
2. The past Presidents.
3. The President and Vice-Presidents for the time being.
4. The President and Vice-Presidents elect.
5. The past and present General Treasurers, General and Assistant General Secretaries.
6. The Local Treasurer and Secretaries for the ensuing Meeting.
7. Ordinary Members.

(2) The Ordinary Members shall be elected annually from the General Committee.

(3) There shall be not more than twenty-five Ordinary Members, of whom not more than twenty shall have served on the Council, as Ordinary Members, in the previous year.

(4) In order to carry out the foregoing rule, the following Ordinary Members of the outgoing Council shall at each annual election be ineligible for nomination:—1st, those who have served on the Council for the greatest number of consecutive years; and, 2nd, those who, being resident in or near London, have attended the fewest number of Meetings during the year—observing (as nearly as possible) the proportion of three by seniority to two by least attendance.

(5) The Council shall submit to the General Committee in their Annual Report the names of the Members of the General Committee whom they recommend for election as Members of Council.

(6) The Election shall take place at the same time as that of the Officers of the Association.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

[1] Passed by the General Committee at Belfast, 1874.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., Esq., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell ,M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, Esq., F.R.S., Astronomer Royal, &c. John Dalton, Esq., D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1884.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, Esq., M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, Esq., D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Esq., Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, Esq., F.L.S., &c. Wm. Hutton, Esq., F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	The Marquis of Northampton. The Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. The Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, Esq., M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount-Edgcumbe	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir T. D. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, Esq., D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, Esq., M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, Esq., M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	The Earl of Listowel. Viscount Adare. Sir W. R. Hamilton, Pres. R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. The Rev. Professor Powell, F.R.S.	Henry Clark, Esq., M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford. OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. The Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. De la Beche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, Esq., M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. The Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews. EDINBURGH, July 21, 1850.	The Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. The Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. The Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S. L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal. IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society. BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S. The Earl of Rosse, Pres. R.S., M.R.I.A. Sir Henry T. De la Beche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, Esq., M.D. Professor W. P. Wilson.

WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Phil. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, Esq., M.D., V.P. Hull Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S. L. & E., F.R.A.S. Joseph Brooks Yates, Esq., F.S.A., F.R.G.S.	Joseph Dickinson, Esq., M.D., F.R.S. Thomas Inman, Esq., M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, Esq., LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, Esq., M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugell, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S., F.R.S.E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, Esq., LL.D.
RICHARD OWEN, Esq., M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural History Departments of the British Museum. LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, Esq., M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.Inst.C.E. Joseph Whitworth, Esq., F.R.S., M.Inst.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. The Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord-Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Rev. the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Rev. the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. F. Osler, Esq., F.R.S. J. T. Chance, Esq. The Rev. Charles Evans, M.A.	William Mathews, jun., Esq., M.A., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, Esq., M.D., F.R.S., F.L.S. John Russell Hind, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, Esq., LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St. Andrews	J. Henderson, jun., Esq. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, Esq., M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, Esq., M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S. F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de Malpas Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, Esq., LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S., F.R.S.E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice-General of Scotland Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, C.B., M.P., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E. Professor Balfour, F.R.S. L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
W. B. CARPENTER, Esq., M.D., LL.D., F.R.S., F.L.S. BRIGHTON, August 14, 1872.	The Right Hon. the Earl of Chichester, Lord-Lieutenant of the County of Sussex. His Grace the Duke of Norfolk His Grace the Duke of Richmond, K.G., P.C., D.C.L. His Grace the Duke of Devonshire, K.G., D.C.L., F.G.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S., F.G.S. Dr. Sharpey, LL.D., Sec. R.S., F.L.S. Joseph Prestwich, Esq., F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq.
PROFESSOR ALEXANDER W. WILLIAMSON, Ph.D., F.R.S., F.C.S. BRADFORD, September 17, 1873.	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. The Right Hon. Lord Houghton, D.C.L., F.R.S. The Right Hon. W. E. Forster, M.P. The Mayor of Bradford. Sir John Hawkshaw, F.R.S., F.G.S. J. P. Gassiot, Esq., D.C.L., F.R.S. Professor Phillips, D.C.L., F.R.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL.D., F.R.S. BELFAST, August 19, 1874.	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. The Rev. Dr. Henry. Dr. Andrews, F.R.S. The Rev. Dr. Robinson, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Professor G. Fuller, C.E. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, M.Inst.C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K.C.B., LL.D., F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.

PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S., F.R.S.E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Professor Sir William Thomson, M.A., LL.D., D.C.L., F.R.S., F.R.S.E. Professor Allen Thomson, M.D., LL.D., F.R.S., F.R.S.E. Professor A. C. Ramsay, LL.D., F.R.S., F.G.S. James Young, Esq., F.R.S., F.C.S.	Dr. W. G. Blackie, F.R.G.S. James Grahame, Esq. J. D. Marwick, Esq.
PROFESSOR ALLEN THOMSON, M.D., LL.D., F.R.S., F.R.S.E. PLYMOUTH, August 15, 1877.	The Right Hon. the Earl of Mount-Edgcumbe The Right Hon. Lord Blachford, K.C.M.G. William Spottiswoode, Esq., M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. William Froude, Esq., M.A., C.E., F.R.S. Charles Spence Bate, Esq., F.R.S., F.L.S.	William Adams, Esq. William Square, Esq. Hamilton Whiteford, Esq.
WILLIAM SPOTTISWOODE, Esq., M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S. DUBLIN, August 14, 1878.	The Right Hon. the Lord Mayor of Dublin The Provost of Trinity College, Dublin His Grace the Duke of Abercorn, K.G. The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S., F.G.S. The Right Hon. the Earl of Rosse, B.A., D.C.L., F.R.S., F.R.A.S., M.R.I.A. The Right Hon. Lord O'Hagan, M.R.I.A. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S.	Professor R. S. Ball, M.A., F.R.S. James Goff, Esq. John Norwood, Esq., LL.D. Professor G. Sigerson, M.D.
PROFESSOR G. J. ALLMAN, M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., Pres. L.S. SHEFFIELD, August 20, 1879.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Hon. the Earl of Wharncliffe, F.R.G.S. W. H. Brittain, Esq. (Master Cutler) Professor T. H. Huxley, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S. Professor W. Odling, M.B., F.R.S., F.C.S.	H. Clifton Sorby, Esq., LL.D., F.R.S., F.G.S. J. F. Moss, Esq.
ANDREW CROMBIE RAMSAY, Esq., LL.D., F.R.S., V.P.G.S., Director-General of the Geological Survey of the United Kingdom, and of the Museum of Practical Geology. SWANSEA, August 25, 1880.	The Right Hon. the Earl of Jersey The Mayor of Swansea The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. H. Hussey Vivian, Esq., M.P., F.G.S. L. Ll. Dillwyn, Esq., M.P., F.L.S., F.G.S. J. Gwyn Jeffreys, Esq., LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S.	W. Morgan Esq., Ph.D., F.C.S. James Strick, Esq.
SIR JOHN LUBBOCK, Bart., M.P., D.C.L., LL.D., F.R.S., Pres. L.S., F.G.S. YORK, August 31, 1881.	His Grace the Archbishop of York, D.D., F.R.S. The Right Hon. the Lord Mayor of York The Right Hon. Lord Houghton, D.C.L., F.R.S., F.R.G.S. The Venerable Archdeacon Creyke, M.A. The Hon. Sir W. R. Grove, M.A., D.C.L., F.R.S. Professor G. G. Stokes, M.A., D.C.L., LL.D., Sec. R.S. Sir John Hawkshaw, M.Inst.C.E., F.R.S., F.G.S., F.R.G.S. Allen Thomson, Esq., M.D., LL.D., F.R.S. L. & E. Professor Allman, M.D., LL.D., F.R.S. L. & E., F.L.S.	Rev. Thomas Adams, M.A. Tempest Anderson, Esq., M.D., B.Sc,

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C. W. SIEMENS, Esq., D.C.L., LL.D., F.R.S., F.C.S., M.Inst.C.E. SOUTHAMPTON, August 23, 1882.	The Right Hon. the Lord Mount-Temple Captain Sir F. J. Evans, K.C.B., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty F. A. Abel, Esq., C.B., F.R.S., V.P.C.S., Director of the Chemical Establishment of the War Department Professor De Chaumont, M.D., F.R.S. Major-General A. C. Cooke, R.E., C.B., F.R.G.S., Director-General of the Ordnance Survey. Wyndham S. Portal, Esq. Professor Prestwich, M.A., F.R.S., F.G.S., F.C.S. Philip Lutley Sclater, Esq., M.A., Ph.D., F.R.S., F.L.S., F.G.S.	C. W. A. Jellicoe, Esq. John E. Le Feuvre, Esq. Morris Miles, Esq.
ARTHUR CAYLEY, Esq., M.A., D.C.L., LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge SOUTHPORT, September 19, 1883.	The Right Hon. the Earl of Derby, M.A., LL.D., F.R.S., F.R.G.S. The Right Hon. the Earl of Crawford and Balcarres, LL.D., F.R.S., F.R.A.S. The Right Hon. the Earl of Lathom Principal J. W. Dawson C.M.G., M.A., LL.D., F.R.S., F.G.S. J. G. Greenwood, Esq., LL.D., Vice-Chancellor of the Victoria University Professor H. E. Roscoe, Ph.D., LL.D., F.R.S., F.C.S.	J. H. Ellis, Esq. Dr. Vernon. T. W. Willis, Esq.
The RIGHT HON. LORD RAYLEIGH, M.A., D.C.L., LL.D., F.R.S., F.R.A.S., F.R.G.S., Professor of Experimental Physics in the University of Cambridge. MONTREAL, August 27, 1884.	His Excellency the Governor-General of Canada, G.C.M.G., LL.D. The Right Hon. Sir John Alexander Macdonald, K.C.B., D.C.L., LL.D. The Right Hon. Sir Lyon Playfair, K.C.B., M.P., Ph.D., LL.D., F.R.S.L. & E., F.C.S. The Hon. Sir Alexander Tilloch Galt, G.C.M.G. The Hon. Sir Charles Tupper, K.C.M.G. Chief Justice Sir A. A. Dorion, C.M.G. Principal Sir William Dawson, C.M.G., M.A., LL.D., F.R.S., F.G.S. The Hon. Dr. Chauveau Professor Edward Frankland, M.D., D.C.L., Ph.D., LL.D., F.R.S., F.C.S. W. H. Hingston, Esq., M.D., D.C.L., L.R.C.S.E. Thomas Sterry Hunt, Esq., M.A., D.Sc., LL.D., F.R.S.	S. E. Dawson, Esq. R. A. Ramsay, Esq. S. Rivard, Esq. S. C. Stevenson, Esq. Thos. White, Esq., M.P.
The RIGHT HON. SIR LYON PLAYFAIR, K.C.B. M.P., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. ABERDEEN, September 9, 1885.	His Grace the Duke of Richmond and Gordon, K.G., D.C.L., Chancellor of the University of Aberdeen The Right Hon. the Earl of Aberdeen, LL.D., Lord-Lieutenant of Aberdeenshire The Right Hon. the Earl of Crawford and Balcarres, M.A., LL.D., F.R.S., F.R.A.S. James Matthews, Esq., Lord Provost of the City of Aberdeen Professor Sir William Thomson, M.A., LL.D., F.R.S., F.R.S.E., F.R.A.S. Alexander Bain, Esq., M.A., LL.D., Rector of the University of Aberdeen The Very Rev. Principal Pirie, D.D., Vice-Chancellor of the University of Aberdeen Professor W. H. Flower, LL.D., F.R.S., F.L.S., Pres. Z.S., F.G.S., Director of the Natural History Museum, London Professor John Struthers, M.D., LL.D.	J. W. Crombie, Esq., M.A. Angus Fraser, Esq., M.A., M.D., F.C.S. Professor G. Pirie, M.A.

SIR J. WILLIAM DAWSON, C.M.G., M.A., LL.D., F.R.S., F.G.S., Principal and Vice-Chancellor of McGill University, Montreal, Canada BIRMINGHAM, September 1, 1886.	The Right Hon. the Earl of Bradford, Lord-Lieutenant of Shropshire. The Right Hon. Lord Leigh, D.C.L., Lord-Lieutenant of Warwickshire. The Right Hon. Lord Norton, K.C.M.G. The Right Hon. Lord Wrottesley, Lord-Lieutenant of Staffordshire The Right Rev. the Lord Bishop of Worcester, D.D. Thomas Martineau, Esq., Mayor of Birmingham Professor G. G. Stokes, M.A., D.C.L., LL.D., Pres. R.S. Professor W. A. Tilden, D.Sc., F.R.S., F.C.S. Rev. A. R. Vardy, M.A. Rev. H. W. Watson, D.Sc., F.R.S.	J. Barham Carslake, Esq. Rev. H. W. Crosskey, LL.D., F.G.S. Charles J. Hart, Esq.
SIR H. E. ROSCOE, M.P., D.C.L., LL.D., Ph.D., F.R.S., V.P.C.S. MANCHESTER, August 31, 1887.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Right Hon. the Earl of Derby, K.G., M.A., LL.D., F.R.S., F.R.G.S. The Right Rev. the Lord Bishop of Manchester, D.D. The Right Rev. the Bishop of Salford The Right Worshipful the Mayor of Manchester The Right Worshipful the Mayor of Salford The Vice-Chancellor of the Victoria University The Principal of the Owens College Sir William Roberts, B.A., M.D., F.R.S. Thomas Ashton, Esq., J.P., D.L. Oliver Heywood, Esq., J.P., D.L. James Prescott Joule, Esq., D.C.L., LL.D., F.R.S., F.R.S.E., F.C.S.	F. J. Faraday, Esq., F.L.S., F.S.S. Charles Hopkinson, Esq., B.Sc. Professor A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S. Professor A. H. Young, M.B., F.R.C.S.
SIR FREDERICK J. BRAMWELL, D.C.L., F.R.S., M.Inst.C.E. BATH, September 5, 1888.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somerset The Most Hon. the Marquess of Bath The Right Hon. and Right Rev. the Lord Bishop of Bath and Wells, D.D. The Right Rev. the Bishop of Clifton, D.D. The Right Worshipful the Mayor of Bath The Right Worshipful the Mayor of Bristol Sir F. A. Abel, C.B., D.C.L., F.R.S., V.P.C.S. The Venerable the Archdeacon of Bath, M.A. The Rev. Leonard Blomefield, M.A., F.L.S., F.G.S. Professor Michael Foster, M.A., M.D., LL.D., Sec. R.S., F.L.S., F.C.S. W. S. Gore-Langton, Esq., J.P., D.L. H. D. Skrine, Esq., J.P., D.L. Colonel R. P. Laurie, C.B., M.P. E. R. Wodehouse, Esq., M.P. Jerom Murch, Esq., J.P., D.L.	W. Pumphrey, Esq. J. L. Stothert, Esq., M.Inst.C.E. B. H. Watts, Esq.
PROFESSOR WILLIAM HENRY FLOWER, C.B., LL.D., F.R.S., F.R.C.S., Pres. Z.S., F.L.S., F.G.S., Director of the Natural History Departments of the British Museum NEWCASTLE-UPON-TYNE, September 11, 1889.	His Grace the Duke of Northumberland, K.G., D.C.L., LL.D., Lord Lieutenant of Northumberland The Right Hon. the Earl of Durham, Lord Lieutenant of Durham The Right Hon. the Earl of Ravensworth The Right Rev. the Lord Bishop of Newcastle, D.D. The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S. The Right Hon. John Morley, M.P., LL.D. The Very Rev. the Warden of the University of Durham, D.D. The Right Worshipful the Mayor of Newcastle The Worshipful the Mayor of Gateshead Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S., M.Inst.C.E. Sir Charles Mark Palmer, Bart., M.P.	Professor P. Phillips Bedson, D.Sc., F.C.S. Professor J. Herman Merivale, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR FREDERICK AUGUSTUS ABEL, C.B., D.C.L., D.Sc., F.R.S., P.P.C.S., Hon. M.Inst.C.E. LEEDS, September 3, 1890.	His Grace the Duke of Devonshire, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S. The Most Hon. the Marquess of Ripon, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. The Right Hon. the Earl Fitzwilliam, K.G., F.R.G.S. The Right Rev. the Lord Bishop of Ripon, D.D. The Right Hon. Sir Lyon Playfair, K.C.B., Ph.D., LL.D., M.P., F.R.S., F.C.S. The Right Hon. W. L. Jackson, M.P., F.S.S. The Right Worshipful the Mayor of Leeds Sir James Kitson, Bart., M.Inst.C.E., F.R.G.S. Sir Andrew Fairbairn, M.A.	J. Rawlinson Ford, Esq. Sydney Lupton, Esq., M.A., F.C.S. Professor L. C. Miall, F.L.S., F.G.S. Professor A. Smithells, B.Sc., F.C.S.
WILLIAM HUGGINS, Esq., D.C.L., LL.D., Ph.D., F.R.S., F.R.A.S., Hon. F.R.S.E. CARDIFF, August 19, 1891.	The Right Hon. Lord Windsor, Lord Lieutenant of Glamorganshire The Most Hon. the Marquess of Bute, K.T. The Right Hon. Lord Rayleigh, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S. The Right Hon. Lord Tredegar The Right Hon. Lord Aberdare, G.C.B., F.R.S., F.R.G.S. Sir J. T. D. Llewelyn, Bart., F.Z.S. Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., Pres.G.S., Director-General of the Geological Survey of the United Kingdom Sir Robert Ball, LL.D., F.R.S., F.R.A.S., Royal Astronomer of Ireland	R. W. Atkinson, Esq., B.Sc., F.C.S., F.I.C. Professor H. W. Lloyd Tanner, M.A., F.R.A.S.
SIR ARCHIBALD GEIKIE, LL.D., D.Sc., For. Sec. R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. EDINBURGH, August 3, 1892.	The Right Hon. the Lord Provost of Edinburgh The Most Hon. the Marquess of Lothian, K.T. The Right Hon. the Earl of Rosebery, LL.D., F.R.S., F.R.S.E. The Right Hon. J. H. A. Macdonald, C.B., LL.D., F.R.S., F.R.S.E. Principal Sir William Muir, K.C.S.I., D.C.L. Professor Sir Douglas Maclagan, M.D., Pres.R.S.E. Professor Sir William Turner, F.R.S., F.R.S.E. Professor P. G. Tait, M.A., F.R.S.E. Professor A. Crum Brown, M.D., F.R.S., F.R.S.E., Pres.C.S.	Professor G. F. Armstrong, M.A., M.Inst.C.E., F.R.S.E., F.G.S. F. Grant Ogilvie, Esq., M.A., B.Sc., F.R.S.E. John Harrison, Esq.
DR. J. S. BURDON SANDERSON, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. NOTTINGHAM, September 13, 1893.	His Grace the Duke of St. Albans, Lord Lieutenant of Nottinghamshire His Grace the Duke of Devonshire, K.G., Chancellor of the University of Cambridge His Grace the Duke of Portland, Lord Lieutenant of Caithness His Grace the Duke of Newcastle The Right Hon. Lord Belper, LL.M. The Right Worshipful the Mayor of Nottingham The Right Hon. Sir W. R. Grove, M.A., D.C.L., LL.D., F.R.S., F.R.S.E. Sir John Turney, J.P. Professor Michael Foster, M.A., M.D., LL.D., Sec.R.S., F.L.S., F.C.S. W. H. Ransom, Esq., M.D., F.R.S.	Professor F. Clowes, D.Sc. Professor W. H. Heaton, M.A. Arthur Williams, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place	Presidents	Secretaries

MATHEMATICAL AND PHYSICAL SCIENCES.

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1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.

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1845. Cambridge	The Very Rev. the Dean of Ely.	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
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1847. Oxford......	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
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1849. Birmingham	William Hopkins, F.R.S.......	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich ...	Rev. W. Whewell, D.D., F.R.S.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast......	Prof. W. Thomson, M.A., F.R.S., F.R.S.E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull.........	The Very Rev. the Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.

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1879. Sheffield ...	George Johnstone Stoney, M.A., F.R.S.	A. H. Allen, J. W. L. Glaisher, Dr. O. J. Lodge, D. MacAlister.

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1888. Bath	Prof. G. F. Fitzgerald, M.A., F.R.S.	R. E. Baynes, R. T. Glazebrook, A. Lodge, W. N. Shaw.
1889. Newcastle-upon-Tyne	Capt. W. de W. Abney, C.B., R.E., F.R.S.	R. E. Baynes, R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. H. Stroud.
1890. Leeds	J. W. L. Glaisher, Sc.D., F.R.S., V.P.R.A.S.	R. T. Glazebrook, Prof. A. Lodge, W. N. Shaw, Prof. W. Stroud.
1891. Cardiff	Prof. O. J. Lodge, D.Sc., LL.D., F.R.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Prof. A. L. Selby.
1892. Edinburgh	Prof. A. Schuster, Ph.D., F.R.S., F.R.A.S.	R. E. Baynes, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.
1893. Nottingham	R. T. Glazebrook, M.A., F.R.S.	W. T. A. Emtage, J. Larmor, Prof. A. Lodge, Dr. W. Peddie.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford......	John Dalton, D.C.L., F.R.S.	James F. W. Johnston.
1833. Cambridge	John Dalton, D.C.L., F.R.S.	Prof. Miller.
1834. Edinburgh	Dr. Hope..........................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin......	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.......	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle	Rev. William Whewell, F.R.S.	Prof. Miller, H. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Dr. Golding Bird, Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S.	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester	John Dalton, D.C.L., F.R.S.	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork.........	Prof. Apjohn, M.R.I.A.........	R. Hunt, Dr. Sweeny.
1844. York.........	Prof. T. Graham, F.R.S.	Dr. L. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.

Date and Place	Presidents	Secretaries
1846. Southampton.	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford......	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.......	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast......	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S. ...	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin......	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen...	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford......	Prof. B. C. Brodie, F.R.S......	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. H. Miller, M.A., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath.........	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton ...	Dr. J. H. Gladstone, F.R.S....	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford ...	Prof. W. J. Russell, F.R.S....	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast......	Prof. A. Crum Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.
1876. Glasgow ...	W. H. Perkin, F.R.S.	W. Dittmar, W. Chandler Roberts, J. M. Thomson, W. A. Tilden.
1877. Plymouth...	F. A. Abel, F.R.S., F.C.S. ...	Dr. Oxland, W. Chandler Roberts, J. M. Thomson.
1878. Dublin	Prof. Maxwell Simpson, M.D., F.R.S., F.C.S.	W. Chandler Roberts, J. M. Thomson, Dr. C. R. Tichborne, T. Wills.

Date and Place	Presidents	Secretaries
1879. Sheffield ...	Prof. Dewar, M.A., F.R.S.	H. S. Bell, W. Chandler Roberts, J. M. Thomson.
1880. Swansea ...	Joseph Henry Gilbert, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, Dr. W. R. Eaton Hodgkinson, J. M. Thomson.
1881. York.........	Prof. A. W. Williamson, Ph.D., F.R.S.	P. Phillips Bedson, H. B. Dixon, T. Gough.
1882. Southampton.	Prof. G. D. Liveing, M.A., F.R.S.	P. Phillips Bedson, H. B. Dixon, J. L. Notter.
1883. Southport	Dr. J. H. Gladstone, F.R.S...	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley.
1884. Montreal ...	Prof. Sir H. E. Roscoe, Ph.D., LL.D., F.R.S.	Prof. P. Phillips Bedson, H. B. Dixon, T. McFarlane, Prof. W. H. Pike.
1885. Aberdeen...	Prof. H. E. Armstrong, Ph.D., F.R.S., Sec. C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, Dr. W. J. Simpson.
1886. Birmingham	W. Crookes, F.R.S., V.P.C.S.	Prof. P. Phillips Bedson, H. B. Dixon, H. Forster Morley, W. W. J. Nicol, C. J. Woodward.
1887. Manchester	Dr. E. Schunck, F.R.S., F.C.S.	Prof. P. Phillips Bedson, H. Forster Morley, W. Thomson.
1888. Bath.........	Prof. W. A. Tilden, D.Sc., F.R.S., V.P.C.S.	Prof. H. B. Dixon, Dr. H. Forster Morley, R. E. Moyle, Dr. W. W. J. Nicol.
1889. Newcastle-upon-Tyne	Sir I. Lowthian Bell, Bart., D.C.L., F.R.S., F.C.S.	Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol, H. L. Pattinson, jun.
1890. Leeds	Prof. T. E. Thorpe, B.Sc., Ph.D., F.R.S., Treas. C.S.	C. H. Bothamley, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.
1891. Cardiff......	Prof. W. C. Roberts-Austen, C.B., F.R.S., F.C.S.	C. H. Bothamley, Dr. H. Forster Morley, Dr. W. W. J. Nicol, Dr. G. S. Turpin.
1892. Edinburgh	Prof. H. McLeod, F.R.S., F.C.S.	Dr. J. Gibson, Dr. H. Forster Morley, D. H. Nagel, Dr. W. W. J. Nicol.
1893. Nottingham	Prof. J. Emerson Reynolds, M.D., D.Sc., F.R.S.	J. B. Coleman, M. J. R. Dunstan, D. H. Nagel, Dr. W. W. J. Nicol.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford......	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge.	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh.	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin......	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol......	Rev. Dr. Buckland, F.R.S.—*Geography*, R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography*, Captain H. M. Denham, R.N.
1838. Newcastle..	C. Lyell, F.R.S., V.P.G.S.—*Geography*, Lord Prudhoe.	W. C. Trevelyan, Capt. Portlock.—*Geography*, Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place	Presidents	Secretaries
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth...	H. T. De la Beche, F.R.S. ...	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork.........	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York.........	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge.	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton.	Leonard Horner, F.R.S.—*Geography*, G. B. Greenough, F.R.S.	Robert A. Austen, Dr. J. H. Norton, Prof. Oldham.—*Geography*, Dr. C. T. Beke.
1847. Oxford......	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh[1]	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Prof. Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.........	Prof. Harkness, William Lawton.
1854. Liverpool..	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S....	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S....	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. D. C. L. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.

[1] At a meeting of the General Committee held in 1850, it was resolved 'That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section,"' for Presidents and Secretaries of which see page lvi.

Date and Place	Presidents	Secretaries
1864. Bath.........	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee ...	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M.Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, T. McKenny Hughes, L. C. Miall.
1872. Brighton ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford ...	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast......	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.
1876. Glasgow ...	Prof. John Young, M.D.	J.Armstrong, F.W.Rudler, W.Topley.
1877. Plymouth...	W. Pengelly, F.R.S., F.G.S.	Dr. Le Neve Foster, R. H. Tiddeman, W. Topley.
1878. Dublin......	John Evans, D.C.L., F.R.S., F.S.A., F.G.S.	E. T. Hardman, Prof. J. O'Reilly, R. H. Tiddeman.
1879. Sheffield ...	Prof. P. Martin Duncan, M.B., F.R.S., F.G.S.	W. Topley, G. Blake Walker.
1880. Swansea ...	H. C. Sorby, LL.D., F.R.S., F.G.S.	W. Topley, W. Whitaker.
1881. York.........	A. C. Ramsay, LL.D., F.R.S., F.G.S.	J. E. Clark, W. Keeping, W. Topley, W. Whitaker.
1882. Southampton.	R. Etheridge, F.R.S., F.G.S.	T. W. Shore, W. Topley, E. Westlake, W. Whitaker.
1883. Southport	Prof. W. C. Williamson, LL.D., F.R.S.	R. Betley, C. E. De Rance, W. Topley, W. Whitaker.
1884. Montreal ...	W. T. Blanford, F.R.S., Sec. G.S.	F. Adams, Prof. E. W. Claypole, W. Topley, W. Whitaker.
1885. Aberdeen ...	Prof. J. W. Judd, F.R.S., Sec. G.S.	C. E. De Rance, J. Horne, J. J. H. Teall, W. Topley.
1886. Birmingham	Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.	W. J. Harrison, J. J. H. Teall, W. Topley, W. W. Watts.
1887. Manchester	Henry Woodward, LL.D., F.R.S., F.G.S.	J. E. Marr, J. J. H. Teall, W. Topley, W. W. Watts.
1888. Bath.........	Prof. W. Boyd Dawkins, M.A., F.R.S., F.G.S.	Prof. G. A. Lebour, W. Topley, W. W. Watts, H. B. Woodward.
1889. Newcastle-upon-Tyne	Prof. J. Geikie, LL.D., D.C.L., F.R.S., F.G.S.	Prof. G. A. Lebour, J. E. Marr, W. W. Watts, H. B. Woodward.
1890. Leeds	Prof. A. H. Green, M.A., F.R.S., F.G.S.	J. E. Bedford, Dr. F. H. Hatch, J. E. Marr, W. W. Watts.
1891. Cardiff	Prof. T. Rupert Jones, F.R.S., F.G.S.	W. Galloway, J. E. Marr, Clement Reid, W. W. Watts.
1892. Edinburgh	Prof. C. Lapworth, LL.D., F.R.S., F.G.S.	H. M. Cadell, J. E. Marr, Clement Reid, W. W. Watts.
1893. Nottingham	J. J. H. Teall, M.A., F.R.S., F.G.S.	J. W. Carr, J. E. Marr, Clement Reid, W. W. Watts.

Date and Place	Presidents	Secretaries

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford......	Rev. P. B. Duncan, F.G.S. ...	Rev. Prof. J. S. Henslow.
1833. Cambridge[1]	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh.	Prof. Graham....................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin......	Dr. Allman........................	J. Curtis, Dr. Litton.
1836. Bristol......	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool...	W. S. MacLeay..................	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Birmingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D......	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork.........	William Thompson, F.L.S....	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. the Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S....	Dr. Lankester, T. V. Wollaston.
1846. Southampton.	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford......	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. lv.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.........	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S.	Dr. Lankester, Dr. Russell.
1850. Edinburgh	Prof. Goodsir, F.R.S. L. & E.	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich ...	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast......	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull.........	C. C. Babington, M.A., F.R.S.	Robert Harrison, Dr. E. Lankester.
1854. Liverpool...	Prof. Balfour, M.D., F.R.S....	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E.	William Keddie, Dr. Lankester.
1856. Cheltenham	Thomas Bell, F.R.S., Pres.L.S.	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin......	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.

[1] At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. lv.

Date and Place	Presidents	Secretaries
1858. Leeds	C. C. Babington, M.A., F.R.S.	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen...	Sir W. Jardine, Bart., F.R.S.E.	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford......	Rev. Prof. Henslow, F.L.S....	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester	Prof. C. C. Babington, F.R.S.	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle	Prof. Balfour, M.D.. F.R.S....	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath.........	Dr. John E. Gray, F.R.S. ...	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S. ...	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY.[1]

1866. Nottingham	Prof. Huxley, LL.D., F.R.S. —*Physiological Dep.*, Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.*, Alf. R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee ...	Prof. Sharpey, M.D., Sec. R.S. —*Dep. of Zool. and Bot.*, George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S. —*Dep. of Physiology*, W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter......	George Busk, F.R.S., F.L.S. —*Dep. of Bot. and Zool.*, C. Spence Bate, F.R.S.—*Dep. of Ethno.*, E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, E. Ray Lankester, Prof. Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.*, J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh.	Prof. Allen Thomson, M.D., F.R.S.—*Dep. of Bot. and Zool.*, Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.*, Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir J. Lubbock, Bart., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. Burdon Sanderson, F.R.S.—*Dep. of Anthropol.*, Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Rutherford, M.D.—*Dep. of Anthropol.*, Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.

[1] At a meeting of the General Committee in 1865, it was resolved:—'That the title of Section D be changed to Biology;' and 'That for the word "Subsection," in the rules for conducting the business of the Sections, the word "Department" be substituted.'

Date and Place	Presidents	Secretaries
1874. Belfast	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.*, Dr. Hooker, C.B., Pres.R.S.—*Dep. of Anthrop.*, Sir W.R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.*, Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.*, Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.
1876. Glasgow ...	A. Russel Wallace, F.R.G.S., F.L.S.—*Dep. of Zool. and Bot.*, Prof. A. Newton, M.A., F.R.S.—*Dep. of Anat. and Physiol.*, Dr. J. G. McKendrick, F.R.S.E.	E. R. Alston, Hyde Clarke, Dr. Knox, Prof. W. R. M'Nab, Dr. Muirhead, Prof. Morrison Watson.
1877. Plymouth...	J. Gwyn Jeffreys, LL.D., F.R.S., F.L.S.—*Dep. of Anat. and Physiol.*, Prof. Macalister, M.D.—*Dep. of Anthropol.*, Francis Galton, M.A., F.R.S.	E. R. Alston, F. Brent, Dr. D. J. Cunningham, Dr. C. A. Hingston, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler.
1878. Dublin	Prof. W. H. Flower, F.R.S.—*Dep. of Anthropol.*, Prof. Huxley, Sec. R.S.—*Dep. of Anat. and Physiol.*, R. McDonnell, M.D., F.R.S.	Dr. R. J. Harvey, Dr. T. Hayden, Prof. W. R. M'Nab, Prof. J. M. Purser, J. B. Rowe, F. W. Rudler.
1879. Sheffield ...	Prof. St. George Mivart, F.R.S.—*Dep. of Anthropol.*, E. B. Tylor, D.C.L., F.R.S. —*Dep. of Anat. and Physiol.*, Dr. Pye-Smith.	Arthur Jackson, Prof. W. R. M'Nab, J. B. Rowe, F. W. Rudler, Prof. Schäfer.
1880. Swansea ...	A. C. L. Günther, M.D., F.R.S. —*Dep. of Anat. and Physiol.*, F. M. Balfour, M.A., F.R.S.—*Dep. of Anthropol.*, F. W. Rudler, F.G.S.	G. W. Bloxam, John Priestley, Howard Saunders, Adam Sedgwick.
1881. York.........	Richard Owen, C.B., M.D., F.R.S.—*Dep. of Anthropol.*, Prof. W. H. Flower, LL.D., F.R.S.—*Dep. of Anat. and Physiol.*, Prof. J. S. Burdon Sanderson, M.D., F.R.S.	G. W. Bloxam, W. A. Forbes, Rev. W. C. Hey, Prof. W. R. M'Nab, W. North, John Priestley, Howard Saunders, H. E. Spencer.
1882. Southampton.	Prof. A. Gamgee, M.D., F.R.S. —*Dep. of Zool. and Bot.*, Prof. M. A. Lawson, M.A., F.L.S.—*Dep. of Anthropol.*, Prof. W. Boyd Dawkins, M.A., F.R.S.	G. W. Bloxam, W. Heape, J. B. Nias, Howard Saunders, A. Sedgwick, T. W. Shore, jun.
1883. Southport[1]	Prof. E. Ray Lankester, M.A., F.R.S.—*Dep. of Anthropol.*, W. Pengelly, F.R.S.	G. W. Bloxam, Dr. G. J. Haslam, W. Heape, W. Hurst, Prof. A. M. Marshall, Howard Saunders, Dr. G. A. Woods.
1884. Montreal[2]...	Prof. H. N. Moseley, M.A., F.R.S.	Prof. W. Osler, Howard Saunders, A. Sedgwick, Prof. R. R. Wright.

[1] By direction of the General Committee at Southampton (1882) the Departments of Zoology and Botany and of Anatomy and Physiology were amalgamated.

[2] By authority of the General Committee, Anthropology was made a separate Section, for Presidents and Secretaries of which see p. lxii.

Date and Place	Presidents	Secretaries
1885. Aberdeen ...	Prof. W. C. McIntosh, M.D., LL.D., F.R.S. F.R.S.E.	W. Heape, J. McGregor-Robertson, J. Duncan Matthews, Howard Saunders, H. Marshall Ward.
1886. Birmingham	W. Carruthers, Pres. L.S., F.R.S., F.G.S.	Prof. T. W. Bridge, W. Heape, Prof. W. Hillhouse, W. L. Sclater, Prof. H. Marshall Ward.
1887. Manchester	Prof. A. Newton, M.A., F.R.S., F.L.S., V.P.Z.S.	C. Bailey, F. E. Beddard, S. F. Harmer, W. Heape, W. L. Sclater, Prof. H. Marshall Ward.
1888. Bath	W. T. Thiselton-Dyer, C.M.G., F.R.S., F.L.S.	F. E. Beddard, S. F. Harmer, Prof. H. Marshall Ward, W. Gardiner, Prof. W. D. Halliburton.
1889. Newcastle-upon-Tyne	Prof. J. S. Burdon Sanderson, M.A., M.D., F.R.S.	C. Bailey, F. E. Beddard, S. F. Harmer, Prof. T. Oliver, Prof. H. Marshall Ward.
1890. Leeds	Prof. A. Milnes Marshall, M.A., M.D., D.Sc., F.R.S.	S. F. Harmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Prof. F. W. Oliver, H. Wager, Prof. H. Marshall Ward.
1891. Cardiff	Francis Darwin, M.A., M.B., F.R.S., F.L.S.	F. E. Beddard, Prof. W. A. Herdman, Dr. S. J. Hickson, G. Murray, Prof. W. N. Parker, H. Wager.
1892. Edinburgh	Prof. W. Rutherford, M.D., F.R.S., F.R.S.E.	G. Brook, Prof. W. A. Herdman, G. Murray, Prof. W. Stirling, H. Wager.
1893. Nottingham	Rev. Canon H. B. Tristram, M.A., LL.D., F.R.S.	G. C. Bourne, Prof. J. B. Farmer, Prof. W. A. Herdman, Dr. S. J. Hickson, Dr. W. B. Ransom, W. L. Sclater.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E (UNTIL 1847).—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard......................	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S....	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D.	Dr. J. Brown, Prof. Couper, Prof. Reid.

SECTION E.—PHYSIOLOGY.

1841. Plymouth ...	P. M. Roget, M.D., Sec. R.S.	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester	Edward Holme, M.D., F.L.S.	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D. ...	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.
1845. Cambridge	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.

Date and Place	Presidents	Secretaries
1846. Southampton.	Prof. Owen, M.D., F.R.S. ...	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford[1] ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S.	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin......	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen...	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford......	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester	Dr. John Davy, F.R.S. L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge	G. E. Paget, M.D...............	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath.........	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birmingham.[2]	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xlix.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard.....................	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A. ...	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Edinburgh	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast......	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull.........	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin......	Rev. Dr. J. Henthorn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.

[1] By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of 'Section D—Zoology and Botany, including Physiology' (see p. lii.). Section E, being then vacant, was assigned in 1851 to Geography.

[2] *Vide* note on page liii.

Date and Place	Presidents	Secretaries
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen...	Rear - Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Prof. Geddes, Dr. Norton Shaw.
1860. Oxford......	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lemprière, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.........	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.........	J.W.Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath.........	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee ...	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, Clements R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich ...	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, Clements R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool...	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H.W.Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh	Colonel Yule, C.B., F.R.G.S.	A. Buchan, A. Keith Johnston, Clements R. Markham, J. H. Thomas.
1872. Brighton ...	Francis Galton, F.R.S.........	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford ...	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast......	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol......	Lieut. - General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.
1876. Glasgow ...	Capt. Evans, C.B., F.R.S.......	H. W. Bates, E. C. Rye, R. Oliphant Wood.
1877. Plymouth...	Adm. Sir E. Ommanney, C.B., F.R.S., F.R.G.S., F.R.A.S.	H. W. Bates, F. E. Fox, E. C. Rye.
1878. Dublin......	Prof. Sir C. Wyville Thomson, LL.D., F.R.S., F.R.S.E.	John Coles, E. C. Rye.
1879. Sheffield ...	Clements R. Markham, C.B., F.R.S., Sec. R.G.S.	H. W. Bates, C. E. D. Black, E. C. Rye.
1880. Swansea ...	Lieut.-Gen. Sir J. H. Lefroy, C.B., K.C.M.G., R.A., F.R.S., F.R.G.S.	H. W. Bates, E. C. Rye.
1881. York.........	Sir J. D. Hooker, K.C.S.I., C.B., F.R.S.	J. W. Barry, H. W. Bates.
1882. Southampton.	Sir R. Temple, Bart., G.C.S.I., F.R.G.S.	E. G. Ravenstein, E. C. Rye.
1883. Southport	Lieut.-Col. H. H. Godwin-Austen, F.R.S.	John Coles, E. G. Ravenstein, E. C. Rye.

Date and Place	Presidents	Secretaries
1884. Montreal ...	Gen. Sir J. H. Lefroy, C.B., K.C.M.G., F.R.S., V.P.R.G.S.	Rev. Abbé Laflamme, J. S. O'Halloran, E. G. Ravenstein, J. F. Torrance.
1885. Aberdeen...	Gen. J. T. Walker, C.B., R.E., LL.D., F.R.S.	J. S. Keltie, J. S. O'Halloran, E. G. Ravenstein, Rev. G. A. Smith.
1886. Birmingham	Maj.-Gen. Sir. F. J. Goldsmid, K.C.S.I., C.B., F.R.G.S.	F. T. S. Houghton, J. S. Keltie, E. G. Ravenstein.
1887. Manchester	Col. Sir C. Warren, R.E., G.C.M.G., F.R.S., F.R.G.S.	Rev. L. C. Casartelli, J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1888. Bath.........	Col. Sir C. W. Wilson, R.E., K.C.B., F.R.S., F.R.G.S.	J. S. Keltie, H. J. Mackinder, E. G. Ravenstein.
1889. Newcastle-upon-Tyne	Col. Sir F. de Winton, K.C.M.G., C.B., F.R.G.S.	J. S. Keltie, H. J. Mackinder, R. Sulivan, A. Silva White.
1890. Leeds	Lieut.-Col. Sir R. Lambert Playfair, K.C.M.G., F.R.G.S.	A. Barker, John Coles, J. S. Keltie, A. Silva White.
1891. Cardiff......	E. G. Ravenstein, F.R.G.S., F.S.S.	John Coles, J. S. Keltie, H. J. Mackinder, A. Silva White, Dr. Yeats.
1892. Edinburgh	Prof. J. Geikie, D.C.L., F.R.S., V.P.R.Scot.G.S.	J. G. Bartholomew, John Coles, J. S. Keltie, A. Silva White.
1893. Nottingham	H. Seebohm, Sec. R.S., F.L.S., F.Z.S.	Col. F. Bailey, John Coles, H. O. Forbes, Dr. H. R. Mill.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.......	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol......	Sir Chas. Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool...	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S..........	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow ...	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth...	Lieut.-Col. Sykes, F.R.S.......	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S. ...	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork.........	Sir C. Lemon, Bart., M.P. ...	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York.........	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. the Earl Fitzwilliam	J. Fletcher, Dr. W. Cooke Tayler.
1846. Southampton.	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford......	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S. ...	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton......	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.

Date and Place	Presidents	Secretaries
1851. Ipswich ...	Sir John P. Boileau, Bart. ...	J. Fletcher, Prof. Hancock.
1852. Belfast......	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, jun.
1853. Hull.........	James Heywood, M.P., F.R.S.	Edward Cheshire, W. Newmarch.
1854. Liverpool...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow ...	R. Monckton Milnes, M.P. ...	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock, W. Newmarch, W. M. Tartt.
1857. Dublin......	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S....	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle .	William Tite, M.P., F.R.S. ...	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...........	R. Birkin, jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant-Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	E. Macrory, F. Purdy, C. T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton ...	Prof. Henry Fawcett, M.P. ...	J. G. Fitch, Barclay Phillips.
1873. Bradford ...	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast......	Lord O'Hagan	Prof. Donnell, F. P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres. S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.
1876. Glasgow ...	Sir George Campbell, K.C.S.I., M.P.	A. M'Neel Caird, T. G. P. Hallett, Dr. W. Neilson Hancock, Dr. W. Jack.
1877. Plymouth...	Rt. Hon. the Earl Fortescue	W. F. Collier, P. Hallett, J. T. Pim.
1878. Dublin	Prof. J. K. Ingram, LL.D., M.R.I.A.	W. J. Hancock, C. Molloy, J. T. Pim.
1879. Sheffield ...	G. Shaw Lefevre, M.P., Pres. S.S.	Prof. Adamson, R. E. Leader, C. Molloy.
1880. Swansea ...	G. W. Hastings, M.P.	N. A. Humphreys, C. Molloy.
1881. York.........	Rt. Hon. M. E. Grant-Duff, M.A., F.R.S.	C. Molloy, W. W. Morrell, J. F. Moss.

Date and Place	Presidents	Secretaries
1882. Southampton.	Rt. Hon. G. Sclater-Booth, M.P., F.R.S.	G. Baden-Powell, Prof. H. S. Foxwell, A. Milnes, C. Molloy.
1883. Southport	R. H. Inglis Palgrave, F.R.S.	Rev. W. Cunningham, Prof. H. S. Foxwell, J. N. Keynes, C. Molloy.
1884. Montreal ...	Sir Richard Temple, Bart., G.C.S.I., C.I.E., F.R.G.S.	Prof. H. S. Foxwell, J. S. McLennan, Prof. J. Watson.
1885. Aberdeen...	Prof. H. Sidgwick, LL.D., Litt.D.	Rev. W. Cunningham, Prof. H. S. Foxwell, C. McCombie, J. F. Moss.
1886. Birmingham	J. B. Martin, M.A., F.S.S.	F. F. Barham, Rev. W. Cunningham, Prof. H. S. Foxwell, J. F. Moss.
1887. Manchester	Robert Giffen, LL.D.,V.P.S.S.	Rev. W. Cunningham, F. Y. Edgeworth, T. H. Elliott, C. Hughes, Prof. J. E. C. Munro, G. H. Sargant.
1888. Bath.........	Rt. Hon. Lord Bramwell, LL.D., F.R.S.	Prof. F. Y. Edgeworth, T. H. Elliott, Prof. H. S. Foxwell, L. L. F. R. Price.
1889. Newcastle-upon-Tyne	Prof. F. Y. Edgeworth, M.A., F.S.S.	Rev. Dr. Cunningham, T. H. Elliott, F. B. Jevons, L. L. F. R. Price.
1890. Leeds	Prof. A. Marshall, M.A., F.S.S.	W. A. Brigg, Rev. Dr. Cunningham, T. H. Elliott, Prof. J. E. C. Munro, L. L. F. R. Price.
1891. Cardiff......	Prof. W. Cunningham, D.D., D.Sc., F.S.S.	Prof. J. Brough, E. Cannan, Prof. E. C. K. Gonner, H. Ll. Smith, Prof. W. R. Sorley.
1892. Edinburgh	Hon. Sir C. W. Fremantle, K.C.B.	Prof. J. Brough, J. R. Findlay, Prof. E. C. K. Gonner, H. Higgs, L. L. F. R. Price.
1893. Nottingham	Prof. J. S. Nicholson, D.Sc., F.S.S.	Prof. E. C. K. Gonner, H. de B. Gibbins, J. A. H. Green, H. Higgs, L. L. F. R. Price.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol......	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.......	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robt. Stephenson.	W. Carpmael, William Hawkes, T. Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork.........	Prof. J. Macneill, M.R.I.A....	James Thomson, Robert Mallet.
1844. York.........	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S..........	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, jun., Charles Manby.
1847. Oxford......	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea ...	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robt. Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. R. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S..........	John Head, Charles Manby.

Date and Place	Presidents	Secretaries
1852. Belfast......	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull.........	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.
1854. Liverpool...	John Scott Russell, F.R.S. ...	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, jun., H. M. Jeffery.
1857. Dublin......	Rt. Hon. the Earl of Rosse, F.R.S.	Prof. Downing, W.T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds	William Fairbairn, F.R.S. ...	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen...	Rev. Prof. Willis, M.A., F.R.S.	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester	J. F. Bateman, C.E., F.R.S....	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle	Rev. Prof. Willis, M.A., F.R.S.	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath.........	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P. Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. O. Tarbotton.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S.	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.........	P. Le Neve Foster, H. Bauerman.
1870. Liverpool...	Chas. B. Vignoles, C.E., F.R.S.	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S.	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E.	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, E. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast......	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S.	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.
1876. Glasgow ...	C. W. Merrifield, F.R.S.	W. Bottomley, jun., W. J. Millar, J. N. Shoolbred, J. P. Smith.
1877. Plymouth...	Edward Woods, C.E.	A. T. Atchison, Dr. Merrifield, J. N. Shoolbred.
1878. Dublin	Edward Easton, C.E.	A. T. Atchison, R. G. Symes, H. T. Wood.
1879. Sheffield ...	J. Robinson, Pres. Inst. Mech. Eng.	A. T. Atchison, Emerson Bainbridge, H. T. Wood.
1880. Swansea ...	James Abernethy, V.P. Inst. C.E., F.R.S.E.	A. T. Atchison, H. T. Wood.
1881. York.........	Sir W. G. Armstrong, C.B., LL.D., D.C.L., F.R.S.	A. T. Atchison, J. F. Stephenson, H. T. Wood.
1882. Southampton	John Fowler, C.E., F.G.S. ...	A. T. Atchison, F. Churton, H. T. Wood.

Date and Place	Presidents	Secretaries
1883. Southport	James Brunlees, F.R.S.E., Pres.Inst.C.E.	A. T. Atchison, E. Rigg, H. T. Wood.
1884. Montreal ...	Sir F. J. Bramwell, F.R.S., V.P. Inst.C.E.	A. T. Atchison, W. B. Dawson, J. Kennedy, H. T. Wood.
1885. Aberdeen...	B. Baker, M.Inst.C.E.	A. T. Atchison, F. G. Ogilvie, E. Rigg, J. N. Shoolbred.
1886. Birmingham	Sir J. N. Douglass, M.Inst. C.E.	C. W. Cooke, J. Kenward, W. B. Marshall, E. Rigg.
1887. Manchester	Prof. Osborne Reynolds, M.A., LL.D., F.R.S.	C. F. Budenberg, W. B. Marshall, E. Rigg.
1888. Bath	W. H. Preece, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, E. Rigg, P. K. Stothert.
1889. Newcastle-upon-Tyne	W. Anderson, M.Inst.C.E. ...	C. W. Cooke, W. B. Marshall, Hon. C. A. Parsons, E. Rigg.
1890. Leeds	Capt. A. Noble, C.B., F.R.S. F.R.A.S.	E. K. Clark, C. W. Cooke, W. B. Marshall, E. Rigg.
1891. Cardiff	T. Forster Brown, M.Inst.C.E.,	C. W. Cooke, Prof. A. C. Elliott, W. B. Marshall, E. Rigg.
1892. Edinburgh	Prof. W. C. Unwin, F.R.S., M.Inst.C.E.	C. W. Cooke, W. B. Marshall, W. C. Popplewell, E. Rigg.
1893. Nottingham	Jeremiah Head, M.Inst.C.E., F.C.S.	C. W. Cooke, W. B. Marshall, E. Rigg, H. Talbot.

ANTHROPOLOGICAL SCIENCE.

SECTION H.—ANTHROPOLOGY.

1884. Montreal ...	E. B. Tylor, D.C.L., F.R.S. ...	G. W. Bloxam, W. Hurst.
1885. Aberdeen...	Francis Galton, M.A., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. A. Macgregor.
1886. Birmingham	Sir G. Campbell, K.C.S.I., M.P., D.C.L., F.R.G.S.	G. W. Bloxam, Dr. J. G. Garson, W. Hurst, Dr. R. Saundby.
1887. Manchester	Prof. A. H. Sayce, M.A.	G. W. Bloxam, Dr. J. G. Garson, Dr. A. M. Paterson.
1888. Bath	Lieut.-General Pitt-Rivers, D.C.L., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, J. Harris Stone.
1889. Newcastle-upon-Tyne	Prof. Sir W. Turner, M.B., LL.D., F.R.S.	G. W. Bloxam, Dr. J. G. Garson, Dr. R. Morison, Dr. R. Howden.
1890. Leeds	Dr. J. Evans, Treas.R.S., F.S.A., F.L.S., F.G.S.	G. W. Bloxam, Dr. C. M. Chadwick, Dr. J. G. Garson.
1891. Cardiff	Prof. F. Max Müller, M.A. ...	G. W. Bloxam, Prof. R. Howden, H. Ling Roth, E. Seward.
1892. Edinburgh	Prof. A. Macalister, M.A., M.D., F.R.S.	G. W. Bloxam, Dr. D. Hepburn, Prof. R. Howden, H. Ling Roth.
1893. Nottingham	Dr. R. Munro, M.A., F.R.S.E.	G. W. Bloxam, Rev. T. W. Davies, Prof. R. Howden, F. B. Jevons, J. L. Myres.

LIST OF EVENING LECTURES.

Date and Place	Lecturer	Subject of Discourse
1842. Manchester	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G.B.Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton.	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting Stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S.	The Dodo (*Didus ineptus*).
1848. Swansea	John Percy, M.D., F.R.S.	Metallurgical Operations of Swansea and its Neighbourhood.
	W. Carpenter, M.D., F.R.S.	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying Velocities on Railways.
1850. Edinburgh	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connection with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G.B.Airy, F.R.S., Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent Discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent Discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar Phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of Researches in Terrestrial Magnetism.
1855. Glasgow	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent Discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.

Date and Place	Lecturer	Subject of Discourse
1857 Dublin......	Prof. W. Thomson, F.R.S. ...	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent Discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen...	Sir R. I. Murchison, D.C.L....	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S. ...	Electrical Discharges in highly rarefied Media.
1860. Oxford......	Rev. Prof. Walker, F.R.S. ...	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Royal.	The late Eclipse of the Sun.
1862 Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S............	Organic Chemistry.
1863. Newcastle	Prof. Williamson, F.R.S......	The Chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S........	The Balloon Ascents made for the British Association.
1864. Bath.........	Prof. Roscoe, F.R.S...........	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.........	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham	William Huggins, F.R.S......	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S......	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S......	The Geological Origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of Knowledge regarding Meteors and Meteorites.
1868. Norwich ...	J. Fergusson, F.R.S...........	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer F.R.S. ...	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connection with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S...............	Some recent Investigations and Applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilisation.
1872. Brighton ...	Prof. P. Martin Duncan, M.B., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford ...	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast......	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	W. Spottiswoode, LL.D., F.R.S.	The Colours of Polarised Light.
	F. J. Bramwell, F.R.S..........	Railway Safety Appliances.
1876. Glasgow ...	Prof. Tait, F.R.S.E.	Force.
	Sir Wyville Thomson, F.R.S.	The *Challenger* Expedition.

Date and Place	Lecturer	Subject of Discourse
1877. Plymouth...	W. Warington Smyth, M.A., F.R.S.	The Physical Phenomena connected with the Mines of Cornwall and Devon.
	Prof. Odling, F.R.S.	The new Element, Gallium.
1878. Dublin	G. J. Romanes, F.L.S.	Animal Intelligence.
	Prof. Dewar, F.R.S.	Dissociation, or Modern Ideas of Chemical Action.
1879. Sheffield ...	W. Crookes, F.R.S.	Radiant Matter.
	Prof. E. Ray Lankester, F.R.S.	Degeneration.
1880. Swansea ...	Prof. W. Boyd Dawkins, F.R.S.	Primeval Man.
	Francis Galton, F.R.S.	Mental Imagery.
1881. York.........	Prof. Huxley, Sec. R.S.	The Rise and Progress of Palæontology.
	W. Spottiswoode, Pres. R.S.	The Electric Discharge, its Forms and its Functions.
1882. Southampton.	Prof. Sir Wm. Thomson, F.R.S.	Tides.
	Prof. H. N. Moseley, F.R.S.	Pelagic Life.
1883. Southport	Prof. R. S. Ball, F.R.S.	Recent Researches on the Distance of the Sun.
	Prof. J. G. McKendrick, F.R.S.E.	Galvanic and Animal Electricity.
1884. Montreal ...	Prof. O. J. Lodge, D.Sc.	Dust.
	Rev. W. H. Dallinger, F.R.S.	The Modern Microscope in Researches on the Least and Lowest Forms of Life.
1885. Aberdeen...	Prof. W. G. Adams, F.R.S. ...	The Electric Light and Atmospheric Absorption.
	John Murray, F.R.S.E.	The Great Ocean Basins.
1886. Birmingham	A. W. Rücker, M.A., F.R.S.	Soap Bubbles.
	Prof. W. Rutherford, M.D. ...	The Sense of Hearing.
1887. Manchester	Prof. H. B. Dixon, F.R.S. ...	The Rate of Explosions in Gases.
	Col. Sir F. de Winton, K.C.M.G.	Explorations in Central Africa.
1888. Bath	Prof. W. E. Ayrton, F.R.S. ...	The Electrical Transmission of Power.
	Prof. T. G. Bonney, D.Sc., F.R.S.	The Foundation Stones of the Earth's Crust.
1889. Newcastle-upon-Tyne	Prof. W. C. Roberts-Austen, F.R.S.	The Hardening and Tempering of Steel.
	Walter Gardiner, M.A.	How Plants maintain themselves in the Struggle for Existence.
1890. Leeds	E. B. Poulton, M.A., F.R.S....	Mimicry.
	Prof. C. Vernon Boys, F.R.S.	Quartz Fibres and their Applications.
1891. Cardiff	Prof. L. C. Miall, F.L.S., F.G.S.	Some Difficulties in the Life of Aquatic Insects.
	Prof. A. W. Rücker, M.A., F.R.S.	Electrical Stress.
1892. Edinburgh	Prof. A. Milnes Marshall, D.Sc., F.R.S.	Pedigrees.
	Prof. J. A. Ewing, M.A., F.R.S., F.R.S.E.	Magnetic Induction.
	Prof. A. Smithells, B.Sc.	Flame.
1893. Nottingham	Prof. Victor Horsley, F.R.S.	The Discovery of the Physiology of the Nervous System.

LECTURES TO THE OPERATIVE CLASSES.

Date and Place	Lecturer	Subject of Discourse
1867. Dundee......	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich ...	Prof. Huxley, LL.D., F.R.S.	A Piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S. ...	Experimental Illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool....	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton ...	W. Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford ...	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast......	Prof. Odling, F.R.S.............	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A Piece of Limestone.
1876. Glasgow ...	Commander Cameron, C.B., R.N.	A Journey through Africa.
1877. Plymouth...	W. H. Preece......................	Telegraphy and the Telephone.
1879. Sheffield ...	W. E. Ayrton	Electricity as a Motive Power.
1880. Swansea ...	H. Seebohm, F.Z.S.	The North-East Passage.
1881. York.........	Prof. Osborne Reynolds, F.R.S.	Raindrops, Hailstones, and Snow-flakes.
1882. Southampton.	John Evans, D.C.L., Treas. R.S.	Unwritten History, and how to read it.
1883. Southport	Sir F. J. Bramwell, F.R.S. ...	Talking by Electricity—Telephones.
1884. Montreal ...	Prof. R. S. Ball, F.R.S..........	Comets.
1885. Aberdeen...	H. B. Dixon, M.A.	The Nature of Explosions.
1886. Birmingham	Prof. W. C. Roberts-Austen, F.R.S.	The Colours of Metals and their Alloys.
1887. Manchester	Prof. G. Forbes, F.R.S.	Electric Lighting.
1888. Bath.........	Sir John Lubbock, Bart., M.P., F.R.S.	The Customs of Savage Races.
1889. Newcastle-upon-Tyne	B. Baker, M.Inst.C.E.	The Forth Bridge.
1890. Leeds	Prof. J. Perry, D.Sc., F.R.S.	Spinning Tops.
1891. Cardiff......	Prof. S. P. Thompson, F.R.S.	Electricity in Mining.
1892. Edinburgh	Prof. C. Vernon Boys, F.R.S.	Electric Spark Photographs.
1893. Nottingham	Prof. Vivian B. Lewes.........	Spontaneous Combustion.

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THE BRITISH ASSOCIATION FOR

Dr. THE GENERAL TREASURER'S ACCOUNT,

1892–93. RECEIPTS.

	£	s.	d.
Balance brought forward	328	8	6
Life Compositions	170	0	0
New Annual Members' Subscriptions	300	0	0
Annual Subscriptions	669	0	0
Sale of Associates' Tickets	724	0	0
Sale of Ladies' Tickets	439	0	0
Sale of Publications	120	18	6
Interest on Exchequer Bills	11	11	6
Dividends on Consols	227	18	4
Dividends on India 3 per Cents.	105	6	0
Unexpended Balance of Grant (made in 1891) for investigating the Phenomena accompanying the Discharge of Electricity from Points	6	15	4
Unexpended Grant (made in 1891) for improving a Deep-sea Tow-net	40	0	0
	£3142	18	2

Investments.

	£	s.	d.
In hands of Trustees:			
$2\frac{3}{4}$ per cent. Consolidated Annuities	8500	0	0
India 3 per cent. Stock	3600	0	0
In hands of Treasurer:			
Exchequer Bills	500	0	0
	£12600	0	0

THE ADVANCEMENT OF SCIENCE.

from July 1, 1892, to June 30, 1893. *Cr.*

1892–93. PAYMENTS.

	£	s.	d.
Expenses of Edinburgh Meeting, including Printing, Advertising, Payment of Clerks, &c.	196	15	0
Rent and Office Expenses	67	18	7
Salaries	500	0	0
Messrs. Spottiswoode & Co., printing, binding, &c.	1079	7	4

GRANTS.

	£	s.	d.	£	s.	d.
Electrical Standards	25	0	0			
Meteorological Observations on Ben Nevis	150	0	0			
Tables of Mathematical Functions	15	0	0			
Recording the Direct Intensity of Solar Radiation	2	8	6			
Magnetic Work at the Falmouth Observatory	25	0	0			
Isomeric Naphthalene Derivatives	20	0	0			
Erratic Blocks	10	0	0			
Fossil Phyllopoda	5	0	0			
Underground Waters	5	0	0			
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0			
Eurypterids of the Pentland Hills	10	0	0			
Table at the Naples Zoological Station	100	0	0			
Table at the Plymouth Biological Laboratory	30	0	0			
Fauna of Sandwich Islands	100	0	0			
Zoology and Botany of West India Islands	50	0	0			
Exploration of Irish Sea	30	0	0			
Physiological Action of Oxygen in Asphyxia	20	0	0			
Index of Genera and Species of Animals	20	0	0			
Exploration of Karakoram Mountains	50	0	0			
Scottish Place-names (10*l.*, less 3*l.* returned)	7	0	0			
Climatology and Hydrography of Tropical Africa	50	0	0			
Methods of Economic Training (4*l.*, less 13*s.* returned)	3	7	0			
Anthropometric Laboratory	5	0	0			
Exploration of Ancient Remains in Abyssinia	25	0	0			
North-Western Tribes of Canada	100	0	0			
Corresponding Societies Committee	30	0	0			
				907	15	6
Balance at Bank of England, Western Branch	424	8	9			
Less Cheques drawn but not presented	39	0	0			
	385	8	9			
In hands of General Treasurer	5	13	0			
				391	1	9
				£3142	18	2

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July 5, 1893.

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.......	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne ...	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26 ...	Birmingham.........	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton......	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D. ...	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.......	314	18
1848, Aug. 9 ...	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12 ...	Birmingham.........	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2 ...	Ipswich	G. B. Airy, Astronomer Royal	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S. ...	194	33
1856, Aug. 6 ...	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds..................	Richard Owen, M.D., D.C.L....	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. the Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A. ...	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1 ...	Cambridge	The Rev. Professor Willis, M.A.	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6 ...	Birmingham.........	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18 ...	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2 ...	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14 ...	Brighton	Dr. W. B. Carpenter, F.R.S. ...	245	36
1873, Sept. 17 ...	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19 ...	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25 ...	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6 ...	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15 ...	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14 ...	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20 ...	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25 ...	Swansea	A. C. Ramsay, LL.D., F.R.S....	144	11
1881, Aug. 31 ...	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23 ...	Southampton	Dr. C. W. Siemens, F.R.S.......	178	17
1883, Sept. 19 ...	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27 ...	Montreal	Prof. Lord Rayleigh, F.R.S. ...	235	20
1885, Sept. 9 ...	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1 ...	Birmingham.........	Sir J.W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31 ...	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5 ...	Bath	Sir F. J. Bramwell, F.R.S.......	266	36
1889, Sept. 11 ...	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3 ...	Leeds.................	Sir F. A. Abel, C.B., F.R.S. ...	259	21
1891, Aug. 19 ...	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3 ...	Edinburgh	Sir A. Geikie, LL.D., F.R.S. ...	280	14
1893, Sept. 13 ...	Nottingham	Prof. J. S. Burdon Sanderson...	201	17

* Ladies were not admitted by purchased tickets until 1843. † Tickets of Admission to Sections only.

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting	Sums paid on Account of Grants for Scientific Purposes	Year
Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total			
...	...	...	...	...	353	....	....	1831
...	...	...	...	...	...	....	....	1832
...	...	...	...	...	900	....	....	1833
...	...	...	...	...	1298	....	£20 0 0	1834
...	...	...	...	...	...	....	167 0 0	1835
...	...	...	...	...	1350	....	435 0 0	1836
...	...	...	...	...	1840	....	922 12 6	1837
...	...	...	1100*	...	2400	....	932 2 2	1838
...	...	...	...	34	1438	....	1595 11 0	1839
...	...	...	...	40	1353	....	1546 16 4	1840
46	317	...	60*	...	891	....	1235 10 11	1841
75	376	33†	331*	28	1315	....	1449 17 8	1842
71	185	...	160	...	...	....	1565 10 2	1843
45	190	9†	260	...	...	....	981 12 8	1844
94	22	407	172	35	1079	....	831 9 9	1845
65	39	270	196	36	857	....	685 16 0	1846
197	40	495	203	53	1320	....	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26&60 H.§	1777	1538 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	35	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	12	2437	2441 0 0	1417 0 11	1889
368	92	680	334	21	1775	1776 0 0	789 16 8	1890
341	152	672	107	12	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893

‡ ncluding Ladies. § Fellows of the American Association were admitted as Hon. Members for this Meeting.

REPORT OF THE COUNCIL.

Report of the Council for the year 1892–93, *presented to the General Committee at Nottingham on Wednesday, September* 13, 1893.

The Council have received reports from the General Treasurer during the past year, and his account from July 1, 1892, to June 30, 1893, which has been audited, will be presented to the General Committee.

Invitations to hold the Annual Meeting of the Association at Bournemouth or at Ipswich in 1895 have been received, and will be brought before the General Committee on Monday; communications in reference to future Meetings of the Association have been received from Liverpool and Toronto.

The Council have been informed that Mr. Arthur P. Johnson, one of the Local Secretaries, having accepted an official appointment in London, was obliged to resign his office, and that Mr. Arthur Williams has allowed himself to be nominated Secretary in his place.

The Council have elected the following Foreign Men of Science, who attended the Meeting at Edinburgh, Corresponding Members :—

Dr. Svante Arrhenius, Stockholm.
Prof. Marcel Bertrand, Paris.
Prof. F. Elfving, Helsingfors.
Prof. Léo Errera, Brussels.
Prof. G. Fritsch, Berlin.
Mr. D. C. Gilman, Baltimore.
Dr. C. E. Guillaume, Sèvres.
Prof. Rosenthal, Erlangen.
Dr. Maurits Snellen, Utrecht.

Resolutions referred to the Council for consideration and action if desirable :—

(*a*) That the Council be requested to draw the attention of the Local Government Board to the desirability of the publication of the 'Report on the Examination into Deviations from the Normal amongst 50,000 Children in various Schools,' which has been presented to that Board by the British Medical Association.

The Council resolved that a letter should be addressed to the President of the Local Government Board in the sense of this resolution :—

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE,
BURLINGTON HOUSE, LONDON, W.,
December 19, 1892.

The Right Hon. Henry Fowler, M.P.,
President of the Local Government Board.

SIR,—The Anthropological and Biological Sections of the British Association for the Advancement of Science at their last meeting had brought before them the question of the Deviation from the Normal in Children in Elementary Schools, in connection with a Report drawn up by a Committee of the International Congress

of Hygiene and Demography. It is understood that this Report has been presented to your Honourable Board by the British Medical Association. The British Association for the Advancement of Science, having regard to the importance of the question from a physiological point of view, as bearing upon the health of the community, passed a resolution requesting the Council of the Association to urge upon your Honourable Board the importance of publishing the Report above referred to, and the Association appointed a committee of their body to continue the further collection of statistics on the subject.

I am therefore instructed by the Council to submit this recommendation, and to urge upon your Honourable Board the importance of the publication of this Report.

I have the honour to be, Sir, your most obedient servant,

ARCH. GEIKIE, *President.*

The following reply was received on January 29 :—

LOCAL GOVERNMENT BOARD, WHITEHALL, S.W.,
January 28, 1893.

SIR,—I am directed by the Local Government Board to acknowledge the receipt of your letter of the 19th ultimo, in which, on behalf of the Council of the British Association for the Advancement of Science, you urge upon the Board the importance of publishing the Report made on behalf of the British Medical Association by Dr. F. Warner on the Physical and Mental condition of 50,000 school children; and to state that, while the Board fully recognise the value of the Report in question, they do not consider that they can undertake its publication.

I am, Sir, your obedient servant,

WM. E. KNOLLYS, *Assistant Secretary.*

Sir A. Geikie,
President of the British Association for the Advancement of Science.

(*b*) That the Council be requested to draw the attention of Her Majesty's Government to the Anthropometric method for the measurement of criminals, which is successfully in operation in France, Austria, and other Continental countries, and which has been found effective in the identification of habitual criminals, and consequently in the prevention and repression of crime.

Council resolved that—

Considering the recognised need of a better system of identification than is now in use in the United Kingdom and its Dependencies, whether for detecting deserters who apply for re-enlistment, or old offenders among those who are accused of crime, or for the prevention of personation, more especially among the illiterate, the Council of the British Association express their opinion that the Anthropometric methods in use in France and elsewhere deserves serious inquiry as to their efficiency, the cost of their maintenance, their general utility, and the propriety of introducing them, or any modification of them, into the Criminal Department of the Home Office, into the Recruiting Departments of the Army and Navy, or into Indian and Colonial Administration.

Copies of this resolution and the following letter, signed by the President of the Association, were sent to the Secretaries of State for the Home Department, Army, Navy, India, and the Colonies :—

June 1893.

The Council of the British Association for the Advancement of Science having had under consideration the question of the best means for the identification of criminals, I am desired to lay before you the inclosed Report on this subject which the Council have adopted. Good evidence has been submitted to them that anthropometric methods, that is to say, the classification of measurements of bodily marks and of finger prints, afford a ready and inexpensive method of identification, and the progress made abroad in organising these methods justifies the hope that the subject may be deemed worthy of serious inquiry by the various Government Departments of this country.

It is believed by the Council that the facilities at the command of these Departments would enable a more correct judgment to be formed, both of the real value to the nation of improved means of identification and of the efficiency and costs of the methods above referred to, than could be obtained through the exertions, however zealous, of private persons.

I therefore venture to hope that you may be willing that inquiries be instituted in the Department over which you preside. The Council will be ready to furnish any information at their disposal which may be desired.

I have the honour to be, your obedient servant,
ARCH. GEIKIE, *President*.

The following replies have been received :—

WAR OFFICE, PALL MALL, S.W., *June* 28, 1893.

SIR,—I am directed by Mr. Secretary Campbell-Bannerman to acknowledge the receipt of your letter of the 19th instant, forwarding a copy of a Report from the British Association for the Advancement of Science relative to the anthropometric method of identifying persons charged with crime.

In reply, I am to acquaint you that the working of this system in France was not long since the subject of careful consideration on the part of the Secretary of State for War, who came to the conclusion that, although the system appeared to be admirably adapted for the identification of criminals, it was not desirable it should be introduced into the British Army.

I am, Sir, your obedient servant,
RALPH THOMPSON.

The President,
British Association for the Advancement of Science,
Burlington House, W.

INDIA OFFICE, WHITEHALL, S.W., *July* 11, 1893.

SIR,—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of the 19th ultimo, and, in reply, to state that anthropometry according to the system invented by M. Bertillon has been introduced into India by the Government, and is now being tried there as an experiment.

I am, Sir, your obedient servant,
GEORGE W. E. RUSSELL.

Sir Archibald Geikie, LL.D., F.R.S., *President*,
British Association for the Advancement of Science,
Burlington House.

ADMIRALTY, *August* 5, 1893.

SIR,—My Lords Commissioners of the Admiralty having had under consideration your letter of the 19th June last, on the subject of an improved mode of registration of physical measurements, &c., of persons entered into the Government services with a view to the identification of criminals, I am commanded by their Lordships to acquaint you that they are not prepared to introduce the Continental system of anthropological examination into the Naval Recruiting Department, as the present mode of noting the physical measurements of all persons who may be entered, together with any particular marks or scars, is deemed sufficient for official purposes, so far as the identification of men is concerned, and that, as a rule, no difficulty arises in identifying deserters.

I am, Sir, your obedient servant,
EVAN MACGREGOR.

Sir Archibald Geikie, LL.D., *President*,
British Association for the Advancement of Science,
Burlington House, W.

(*c*) That the letter of Professor E. Wiedemann and the communications from the Committees of Sections B and C on the subject of the headings of Reports be referred to the Council.

The Council resolved that the subject of a Report should be mentioned first, then the names of the Committee, and finally the titles of any Appendices.

The Council received an invitation from the University and Citizens of Padua to appoint a delegate to attend the celebration of the three hundredth anniversary of the appointment of Galileo to the Chair of Mathematics in the University of Padua, and in accordance with this request they appointed Mr. Ludwig Mond, F.R.S., to join in this celebration.

The Report of the corresponding Societies Committee has been received, and will be presented to the General Committee.

The Corresponding Societies Committee, consisting of Mr. Francis Galton, Professor R. Meldola, Sir Douglas Galton, Sir Rawson Rawson, Dr. J. G. Garson, Sir J. Evans, Mr. J. Hopkinson, Mr. W. Whitaker, Mr. G. J. Symons, Mr. W. Topley, Professor T. G. Bonney, Mr. T. V. Holmes, Mr. E. B. Poulton, Mr. Cuthbert Peek, and the Rev. Canon Tristram, is hereby nominated for reappointment by the General Committee.

The Council nominate Dr. J. G. Garson, Chairman, Mr. G. J. Symons, F.R.S., Vice-Chairman, and Mr. T. V. Holmes, F.G.S., Secretary, to the Conference of Delegates of Corresponding Societies to be held during the Meeting at Nottingham.

An Index to the Reports of the Association from 1831 to 1860 was published in 1864, of which copies are still to be obtained. Mr. Griffith has for some time been engaged on the arduous task of preparing an Index to the Reports from 1861 to 1890.

The Council are glad to be able to announce that this new Index is now in type, and will be on sale at a cost of 15*s.* within a few weeks.

It is evident that the utility of the Annual Reports will be much increased, now that their contents are made more readily accessible by means of a good index.

In accordance with the regulations the retiring Members of the Council will be—

Sir M. E. Grant-Duff.
Prof. G. F. FitzGerald.
Prof. Roberts-Austen.
Prof. Schäfer.
Prof. Schuster.

The Council recommend the re-election of the other ordinary Members of the Council, with the addition of the gentlemen whose names are distinguished by an asterisk in the following list:—

Anderson, Dr. W., F.R.S.
Ayrton, Prof. W. E., F.R.S.
Baker, Sir B., K.C.M.G., F.R.S.
Ball, Sir R. S., F.R.S.
*Boys, Prof. C. Vernon, F.R.S.
Edgeworth, Prof., M.A.
Evans, Sir J., K.C.B., F.R.S.
Glazebrook, R. T., Esq., F.R.S.
Green, Prof. A. H., F.R.S.
*Horsley, Prof. Victor, F.R.S.
Liveing, Prof. G. D., F.R.S.
Lodge, Prof. Oliver J., F.R.S.
*Markham, Clements R., Esq., C.B., F.R.S.
Meldola, Prof. R., F.R.S.
Preece, W. H., Esq., F.R.S.
Ramsay, Prof. W., F.R.S.
Reinold, Prof. A. W., F.R.S.
*Reynolds, Prof. J. Emerson, M.D., F.R.S.
Sidgwick, Prof. H., M.A.
Symons, G. J., Esq., F.R.S.
*Thomson, Prof. J. J., M.A., F.R.S.
Unwin, Prof. W. C., F.R.S.
Ward, Prof. Marshall, F.R.S.
Whitaker, W., Esq., F.R.S.
Woodward, Dr. H., F.R.S.

Committees appointed by the General Committee at the Nottingham Meeting in September 1893.

1. *Receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee	Grants
Making Experiments for improving the Construction of Practical Standards for use in Electrical Measurements.	*Chairman.*—Professor G. Carey Foster. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Professors W. E. Ayrton, J. Perry, W. G. Adams, and Oliver J. Lodge, Lord Rayleigh, Dr. John Hopkinson, Dr. A. Muirhead, Messrs. W. H. Preece and Herbert Taylor, Professors J. D. Everett and A. Schuster, Dr. J. A. Fleming, Professors G. F. FitzGerald, G. Chrystal, and J. J. Thomson, Mr. W. N. Shaw, Dr. J. T. Bottomley, Rev. T. C. Fitzpatrick, Professor J. Viriamu Jones, Dr. G. Johnstone Stoney, Professor S. P. Thompson, and Mr. G. Forbes.	£ s. d. 25 0 0
The Application of Photography to the Elucidation of Meteorological Phenomena. [Last year's grant renewed.]	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. A. W. Clayden. Professor R. Meldola and Mr. John Hopkinson.	10 0 0
For Calculating Tables of certain Mathematical Functions, and, if necessary, for taking steps to carry out the Calculations, and to publish the results in an accessible form.	*Chairman.*—Lord Rayleigh. *Secretary.*—Professor A. Lodge. Lord Kelvin, Professor A. Cayley, Professor B. Price, Dr. J. W. L. Glaisher, Professor A. G. Greenhill, and Professor W. M. Hicks.	15 0 0
Considering the best Methods of Recording the Direct Intensity of Solar Radiation.	*Chairman.*—Sir G. G. Stokes. *Secretary.*—Professor H. McLeod. Professor A. Schuster, Mr. G. Johnstone Stoney, Sir H. E. Roscoe, Captain W. de W. Abney, Mr. C. Chree, Mr. G. J. Symons, and Mr. W. E. Wilson.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To consider the establishment of a National Physical Laboratory for the more accurate determination of Physical Constants, and for other Quantitative Research, and to confer with the Council of the Association.	*Chairman.* — Professor Oliver J. Lodge. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin, Lord Rayleigh, Sir H. E. Roscoe, Professors J. J. Thomson, A. W. Rücker, R. B. Clifton, G. F. FitzGerald, Carey Foster, J. Viriamu Jones, A. Schuster, and W. E. Ayrton.	5 0 0
Preparing a new Series of Wave-length Tables of the Spectra of the Elements. [Last year's grant renewed.]	*Chairman.*—Sir H. E. Roscoe. *Secretary.*—Dr. Marshall Watts. Mr. J. N. Lockyer, Professors J. Dewar, G. D. Liveing, A. Schuster, W. N. Hartley, and Wolcott Gibbs, and Captain Abney.	10 0 0
To consider the best Method of establishing an International Standard for the Analysis of Iron and Steel. [Last year's grant partly renewed.]	*Chairman.* — Professor Roberts-Austen. *Secretary.*—Mr. Thomas Turner. Sir F. Abel, Messrs. E. Riley and J. Spiller, Professor J. W. Langley, Mr. G. J. Snelus, and Professor W. A. Tilden.	15 0 0
The Action of Light upon Dyed Colours. [Last year's grant renewed.]	*Chairman.*—Professor T. E. Thorpe. *Secretary.*—Professor J. J. Hummel. Dr. W. H. Perkin, Prof. W. J. Russell, Captain Abney, Prof. W. Stroud, and Prof. R. Meldola.	5 0 0
Recording the Position, Height above the Sea, Lithological Characters, Size, and Origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. P. F. Kendall. Professors W. Boyd Dawkins, T. McK. Hughes, T. G. Bonney, and J. Prestwich, Dr. H. W. Crosskey, Messrs. C. E. De Rance, R. H. Tiddeman, J. W. Woodall, and Prof. L. C. Miall.	15 0 0
The Description and Illustration of the Fossil Phyllopoda of the Palæozoic Rocks.	*Chairman.*—Rev. Prof. T. Wiltshire. *Secretary.*—Professor T. R. Jones. Dr. H. Woodward.	5 0 0
The Collection, Preservation, and Systematic Registration of Photographs of Geological interest. [Last year's grant renewed.]	*Chairman.*—Professor J. Geikie. *Secretary.*—Mr. O. W. Jeffs. Prof. T. G. Bonney, Prof. Boyd Dawkins, Dr. V. Ball, Dr. T. Anderson, and Messrs. A. S. Reid, E. J. Garwood, W. Gray, H. B. Woodward, J. E. Bedford, R. Kidston, W. W. Watts, R. H. Tiddeman, and J. J. H. Teall.	10 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To investigate the character of the high-level shell-bearing deposits at Clava, Chapelhall, and other localities.	*Chairman.*—Mr. J. Horne. *Secretary.*—Mr. Dugald Bell. Messrs. J. Fraser, P. F. Kendall, J. F. Jamieson, and David Robertson.	20 0 0
The Investigation of the Eurypterid-bearing Deposits of the Pentland Hills.	*Chairman.*—Dr. R. H. Traquair. *Secretary.*—Mr. M. Laurie. Professor T. Rupert Jones.	5 0 0
To open further Sections in the neighbourhood of Stonesfield in order to show the relationship of the 'Stonesfield Slate' to the underlying and overlying strata.	*Chairman.*—Mr. H. B. Woodward. *Secretary.*—Mr. E. A. Walford. Professor A. H. Green, Dr. H. Woodward, and Mr. J. Windoes.	25 0 0
Considering the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions.	*Chairman.*—Mr. G. J. Symons. *Secretary.*—Mr. C. Davison. Sir F. J. Bramwell, Mr. E. A. Cowper, Professor G. H. Darwin, Professor J. A. Ewing, Mr. Isaac Roberts, Mr. Thomas Gray, Sir John Evans, Professor J. Prestwich, Professor E. Hull, Professor G. A. Lebour, Professor R. Meldola, Professor J. W. Judd, Mr. M. Walton Brown, Mr. J. Glaisher, Professor C. G. Knott, Professor J. H. Poynting, and Mr. Horace Darwin.	50 0 0
To explore the Calf Hole Cave, at the Heights, Skyrethorne, near Skipton.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Rev. E. Jones. Professor W. Boyd Dawkins, Professor L. C. Miall, Mr. P. F. Kendall, Mr. A. Birtwhistle, and Mr. J. J. Wilkinson.	5 0 0
Occupation of a Table at the Zoological Station at Naples, to enable Mr. E. S. Moore to investigate the origin of the Reproductive Organs in various types of fishes, &c., and to enable Mr. E. J. Allen to continue his researches on the Decapod Crustacea.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. Percy Sladen. Professor Ray Lankester, Professor J. Cossar Ewart, Professor M. Foster, Professor A. Milnes Marshall, and Mr. A. Sedgwick.	100 0 0
To enable Dr. S. J. Hickson to investigate the development of *Alcyonium* at the Laboratory of the Marine Biological Association, Plymouth.	*Chairman.* — Professor E. Ray Lankester. *Secretary.*—Mr. G. C. Bourne. Professor M. Foster and Professor S. H. Vines.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants
		£ s. d.
To report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the Fauna, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance in their investigations as may be offered by the Hawaiian Government.	*Chairman.*—Professor A. Newton. *Secretary.*—Dr. David Sharp. Dr. W. T. Blanford, Dr. S. J. Hickson, Professor Riley, Mr. O. Salvin, Dr. P. L. Sclater, and Mr. Edgar A. Smith.	100 0 0
The Marine Zoology of the Irish Sea.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Mr. I. C. Thompson. Professor A. C. Haddon, Professor G. B. Howes, Mr. W. E. Hoyle, and Mr. A. O. Walker.	40 0 0
The Structure and Function of the Mammalian Heart.	*Chairman.*—Professor E. A. Schäfer. *Secretary.*—Mr. Stanley Kent. Professor Sherrington.	10 0 0
Climatology and Hydrography of Tropical Africa.	*Chairman.*—Mr. E. G. Ravenstein. *Secretary.*—Dr. H. R. Mill. Mr. G. J. Symons and Mr. Baldwin Latham.	10 0 0
Geographical, Meteorological, and Natural History observations in South Georgia or other Antarctic Island.	*Chairman.* — Mr. Clements R. Markham. *Secretary.*—Dr. H. R. Mill. Mr. J. Y. Buchanan and Mr. H. O. Forbes.	50 0 0
Exploration of Hadramaut, Arabia.	*Chairman.*—Mr. H. Seebohm. *Secretary.*—Mr. J. Theodore Bent. Mr. E. G. Ravenstein, Dr. J. G. Garson, and Mr. G. W. Bloxam.	30 0 0
The Methods of Economic Training adopted in this and other countries.	*Chairman.*—Professor W. Cunningham. *Secretary.*—Professor E. C. K. Gonner. Professor F. Y. Edgeworth, Professor H. S. Foxwell, Mr. H. Higgs, Mr. L. L. Price, and Professor J. S. Nicholson.	10 0 0
For carrying on the Work of the Anthropometric Laboratory.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Dr. J. G. Garson. Mr. G. W. Bloxam, Dr. Wilberforce Smith, Professor A. C. Haddon, and Professor B. C. A. Windle.	5 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee	Grants £ s. d.
To organise an Ethnographical Survey of the United Kingdom.	*Chairman.*—Mr. E. W. Brabrook. *Secretary.*—Mr. G. W. Bloxam. Mr. Francis Galton, Dr. J. G. Garson, Professor A. C. Haddon, Dr. Joseph Anderson, Mr. J. Romilly Allen, Dr. J. Beddoe, Professor D. J. Cunningham, Professor W. Boyd Dawkins, Mr. Arthur Evans, Mr. E. Sidney Hartland, Sir H. Howorth, Professor R. Meldola, General Pitt-Rivers, and Mr. E. G. Ravenstein.	10 0 0
The Lake Village at Glastonbury.	*Chairman.*—Dr. R. Munro. *Secretary.*—Mr. A. Bulleid. Professor W. Boyd Dawkins, General Pitt-Rivers, and Sir John Evans.	40 0 0
Anthropometric Measurements in Schools.	*Chairman.*—Professor J. Cleland. *Secretary.*—Professor B. Windle. Mr. G. W. Bloxam, Mr. E. W. Brabrook, Dr. J. G. Garson, and Professor A. Macalister.	5 0 0
To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the investigation of the Mental and Physical Condition of Children.	*Chairman.*—Sir Douglas Galton. *Secretary.*—Dr. Francis Warner. Mr. G. W. Bloxam, Mr. E. W. Brabrook, Dr. J. G. Garson, and Dr. W. Wilberforce Smith.	20 0 0
Corresponding Societies Committee.	*Chairman.*—Professor R. Meldola. *Secretary.*—Mr. T. V. Holmes. Mr. Francis Galton, Sir Douglas Galton, Sir Rawson Rawson, Mr. G. J. Symons, Dr. J. G. Garson, Sir John Evans, Mr. J. Hopkinson, Professor T. G. Bonney, Mr. W. Whitaker, Mr. W. Topley, Professor E. B. Poulton, Mr. Cuthbert Peek, and Rev. Canon H. B. Tristram.	25 0 0

2. *Not receiving Grants of Money.*

Subject for Investigation or Purpose	Members of the Committee
Co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis.	*Chairman.*—Lord McLaren. *Secretary.*—Professor Crum Brown. Mr. John Murray, Dr. A. Buchan, Professor R. Copeland, and Hon. R. Abercromby.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The various Phenomena connected with the recalescent Points in Iron and other Metals.	*Chairman.*—Professor G. F. FitzGerald. *Secretary.*—Professor W. F. Barrett. Dr. John Hopkinson, Mr. R. A. Hadfield, Mr. F. T. Trouton, Professor W. C. Roberts-Austen, and Mr. H. F. Newall.
The Volcanic and Seismological Phenomena of Japan.	*Chairman.*—Lord Kelvin. *Secretary.*—Professor J. Milne. Professor W. G. Adams, Mr. J. T. Bottomley, Professor A. H. Green, and Professor C. G. Knott.
To investigate the Phenomena accompanying the Discharge of Electricity from Points.	*Chairman.*—Professor Oliver J. Lodge. *Secretary.*—Mr. A. P. Chattock. Professor Carey Foster.
Comparing and Reducing Magnetic Observations.	*Chairman.*—Professor W. G. Adams. *Secretary.*—Professor W. G. Adams. Lord Kelvin, Professor G. H. Darwin, Professor G. Chrystal, Mr. C. H. Carpmael, Professor A. Schuster, Mr. C. Chree, Captain E. W. Creak, the Astronomer Royal, Mr. William Ellis, and Professor A. W. Rücker.
The Collection and Identification of Meteoric Dust.	*Chairman.*—Mr. John Murray. *Secretary.*—Mr. John Murray. Professor A. Schuster, Lord Kelvin, the Abbé Renard, Dr. A. Buchan, the Hon. R. Abercromby, Dr. M. Grabham, and Mr. John Aitken.
The Rate of Increase of Underground Temperature downwards in various Localities of dry Land and under Water.	*Chairman.*—Professor J. D. Everett. *Secretary.*—Professor J. D. Everett. Professor Lord Kelvin, Mr. G. J. Symons, Sir A. Geikie, Mr. J. Glaisher, Mr. W. Pengelly, Professor Edward Hull, Professor J. Prestwich, Dr. C. Le Neve Foster, Professor A. S. Herschel, Professor G. A. Lebour, Mr. A. B. Wynne, Mr. W. Galloway, Mr. Joseph Dickinson, Mr. G. F. Deacon, Mr. E. Wethered, Mr. A. Strahan, and Professor Michie Smith.
To co-operate with Dr. Kerr in his researches on Electro-optics.	*Chairman.*—Dr. John Kerr. *Secretary.*—Mr. R. T. Glazebrook. Lord Kelvin and Professor A. W. Rücker.
That Mr. W. N. Shaw and the Rev. T. C. Fitzpatrick be requested to continue their Report on the present state of our Knowledge in Electrolysis and Electro-chemistry.	—

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
That Dr. J. Larmor and Mr. G. H. Bryan be requested to continue their Report on the present state of our Knowledge in Thermodynamics, specially with regard to the Second Law.	—
The Properties of Solutions . . .	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professor W. Ramsay.
Reporting on the Bibliography of Solution.	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Dr. W. W. J. Nicol. Professors McLeod, Pickering, Ramsay, and Young.
The Continuation of the Bibliography of Spectroscopy.	*Chairman.*—Professor H. McLeod. *Secretary.*—Professor Roberts-Austen. Mr. H. G. Madan and Mr. D. H. Nagel.
The Action of Light on the Hydracids of the Halogens in presence of Oxygen.	*Chairman.*—Dr. W. J. Russell. *Secretary.*—Dr. A. Richardson. Captain Abney and Professors Noel Hartley and W. Ramsay.
To inquire into the Proximate Chemical Constituents of the various kinds of Coal.	*Chairman.*—Sir I. Lowthian Bell. *Secretary.*—Professor P. Phillips Bedson. Mr. Ludwig Mond, Professors Vivian B. Lewes and E. Hull, and Messrs. J. W. Thomas and H. Bauerman.
To report on recent Inquiries into the History of Chemistry.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Professor John Ferguson.
The Investigation of the direct Formation of Haloids from pure Materials.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr. W. A. Shenstone. Professor W. R. Dunstan and Mr. C. H. Bothamley.
Isomeric Naphthalene Derivatives .	*Chairman.*—Professor W. A. Tilden. *Secretary.*—Professor H. E. Armstrong.
The Electrolytic Methods of Quantitative Analysis.	*Chairman.*—Professor J. Emerson Reynolds. *Secretary.*—Dr. C. A. Kohn. Professor Frankland, Professor F. Clowes, Dr. Hugh Marshall, Mr. A. E. Fletcher, Mr. D. H Nagel, Mr. T. Turner, and Mr. — Coleman.
The Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that action.	*Chairman.*—Mr. W. Whitaker. *Secretaries.*—Messrs. C. E. De Rance and W. Topley. Messrs. J. B. Redman and J. W. Woodall, Maj.-Gen. Sir A. Clarke, Admiral Sir E. Ommanney, Capt. Sir G. Nares, Capt. J. Parsons, Capt. W. J. L. Wharton, Professor J. Prestwich, Mr. Edward Easton, Mr. J. S. Valentine, and Professor L. F. Vernon Harcourt.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Volcanic Phenomena of Vesuvius and its neighbourhood.	*Chairman.*—Mr. H. Bauerman. *Secretary.*—Dr. H. J. Johnston-Lavis. Messrs. F. W. Rudler and J. J. H. Teall.
To consider the best Methods for the Registration of all Type Specimens of Fossils in the British Isles, and to report on the same.	*Chairman.*—Dr. H. Woodward. *Secretary.*—Mr. A. Smith Woodward. Rev. G. F. Whidborne, Mr. R. Kidston, and Mr. J. E. Marr.
To complete the Investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether the remains of Palæolithic Man occur in the Lower Cave Earth.	*Chairman.*—Mr. R. H. Tiddeman. *Secretary.*—Rev. E. Jones. Sir J. Evans, Dr. J. G. Garson, Mr. W. Pengelly, and Mr. J. J. Wilkinson.
To carry on Excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock Shelters at that spot.	*Chairman.*—Sir J. Evans. *Secretary.*—Mr. B. Harrison. Professor J. Prestwich and Professor H. G. Seeley.
The Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations. And that a Digest of the eighteen Reports should be prepared by the Committee, and sold in a separate form.	*Chairman.*—Professor E. Hull. *Secretary.*—Mr. C. E. De Rance. Dr. H. W. Crosskey, Sir D. Galton, Professor J. Prestwich, and Messrs. J. Glaisher, P. F. Kendall, E. B. Marten, G. H. Morton, W. Pengelly, I. Roberts, T. S. Stooke, G. J. Symons, W. Topley, C. Tylden-Wright, E. Wethered, and W. Whitaker.
To consider a project for investigating the Structure of a Coral Reef by Boring and Sounding.	*Chairman.*—Professor T. G. Bonney. *Secretary.*—Professor W. J. Sollas. Sir Archibald Geikie, Professors A. H. Green, J. W. Judd, C. Lapworth, A. C. Haddon, Boyd Dawkins, G. H. Darwin, and A. Stewart, Captain W. J. L. Wharton, Drs. H. Hicks, J. Murray, and H. B. Guppy, Messrs. F. Darwin, H. O. Forbes, G. C. Bourne, S. Hickson, A. R. Binnie, and J. W. Gregory, and Hon. P. Fawcett.
For improving and experimenting with a Deep-sea Tow-net for opening and closing under water.	*Chairman.*—Professor A. C. Haddon. *Secretary.*—Mr. W. E. Hoyle. Professor W. A. Herdman.
To report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and to take steps to investigate ascertained deficiencies in the Fauna and Flora.	*Chairman.*—Dr. P. L. Sclater. *Secretary.*—Mr. G. Murray. Mr. W. Carruthers, Dr. A. C. Günther, Dr. D. Sharp, Mr. F. Du Cane Godman, and Professor A. Newton.
To make a Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels.	*Chairman.*—Professor A. Newton. *Secretary.*—Mr. John Cordeaux. Mr. John A. Harvie-Brown, Mr. R. M. Barrington, Mr. W. E. Clarke, and Rev. E. P. Knubley.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
For taking steps to establish a Botanical Laboratory at Peradeniya, Ceylon.	*Chairman.*—Professor M. Foster. *Secretary.*—Professor J. B. Farmer. Professor Bayley Balfour, Mr. Thiselton-Dyer, Dr. H. Trimen, Professor Marshall Ward, Mr. W. Carruthers, Professor M. M. Hartog, Professor F. O. Bower, and Mr. W. Gardiner.
To consider proposals for the Legislative Protection of Wild Birds' Eggs.	*Chairman.*—Sir John Lubbock. *Secretary.*—Mr. H. E. Dresser. Mr. John Cordeaux, Mr. W. H. Hudson, Professor A. Newton, Mr. Howard Saunders, Mr. Thomas Henry Thomas, Canon Tristram, and Dr. C. T. Vachell.
The Collection of Facts and Statistics bearing on the following Questions:— 1. The influence of previous fertilisation of the female on her subsequent offspring. 2. The effect of material impressions during pregnancy on the offspring. The Committee are authorised to communicate with the Councils of the British Medical Society, the Royal Agricultural Society, the Highland Agricultural Society, and the Royal Dublin Society, with the view to joint work.	*Chairman.*—Dr. A. Russel Wallace. *Secretary.*—Dr. James Clark. Dr. G. J. Romanes, Dr. S. J. Hickson, Professor E. A. Schäfer, and Dr. J. N. Langley.
Compilation of an Index Generum et Specierum Animalium.	*Chairman.*—Sir W. H. Flower. *Secretary.*—Mr. W. Sclater. Dr. P. L. Sclater and Dr. H. Woodward.
Scottish Place-names	*Chairman.*—Sir C. W. Wilson. *Secretary.*—Dr. J. Burgess. Mr. Coutts Trotter.
The Teaching of Science in Elementary Schools.	*Chairman.*—Dr. J. H. Gladstone. *Secretary.*—Professor H. E. Armstrong. Mr. S. Bourne, Dr. Crosskey, Mr. George Gladstone, Mr. J. Heywood, Sir J. Lubbock, Sir Philip Magnus, Professor N. Story Maskelyne, Sir H. E. Roscoe, Sir R. Temple, and Professor Silvanus P. Thompson.
To report on Methods of determining the Dryness of Steam in boiler trials.	*Chairman.*—Sir F. J. Bramwell. *Secretary.*—Professor W. C. Unwin. Professor T. H. Beare, Mr. Jeremiah Head, Professor A. B. W. Kennedy, Professor Osborne Reynolds, and Mr. Mair Rumley.

2. *Not receiving Grants of Money*—continued.

Subject for Investigation or Purpose	Members of the Committee
The Prehistoric and Ancient Remains of Glamorganshire.	*Chairman.*—Dr. C. T. Vachell. *Secretary.*—Mr. E. Seward. Lord Bute, Messrs. G. T. Clark, R. W. Atkinson, Franklen G. Evans, James Bell, and T. H. Thomas, and Dr. J. G. Garson.
To consider Uniformity in the Spelling of Barbaric and Savage Languages and Race Names.	*Chairman.*—Mr. F. Galton. *Secretary.*—Mr. C. E. Peek. Dr. E. B. Tylor, Professor A. C. Haddon, Mr. G. W. Bloxam, and Mr. Ling Roth.
The Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada, with power to utilise any portion of last year's grant that may remain after payment of expenses incurred.	*Chairman.*—Dr. E. B. Tylor. *Secretary.*—Mr. G. W. Bloxam. Dr. G. M. Dawson, Mr. R. G. Haliburton, and Mr. H. Hale.

Other Resolutions adopted by the General Committee.

That Dr. J. Larmor's paper entitled 'The Action of Magnetism on Light; with a critical correlation of the various theories of Light-propagation' be printed *in extenso* among the Reports.

That Professor Percy Frankland's paper on 'Bacteriology in its relations to Chemical Science' be printed *in extenso* among the Reports.

That the paper by Mr. W. Worby Beaumont on 'An Automatic Balance of Reciprocating Mechanism' be printed *in extenso* among the Reports.

That at the next Meeting of the Association, and at such future Meetings as may seem to the Council desirable, there should be a separate Section for Physiology, Animal and Vegetable.

That it is desirable that, for the purpose of securing co-ordinate action, a joint Organising Committee be appointed for the purpose of arranging provisionally the Proceedings of the Sections of Biology and Physiology.

Resolutions referred to the Council for consideration, and action if desirable.

That the recommendations regarding the times at which the Sections and Sectional Committees shall meet, which have been received from the Sectional Committees, be referred to the Council.

That the resolution received from the Committees of Sections C and G proposing a change in the rule relating to the appointment of Committees for special objects of Science be referred to the Council.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Nottingham Meeting, September 1893. *The Names of the Members entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

	£	s.	d.
*Foster, Professor Carey—Electrical Standards	25	0	0
*Symons, Mr. G. J.—Photographs of Meteorological Phenomena (renewed)	10	0	0
*Rayleigh, Lord—Tables of Mathematical Functions	15	0	0
*Stokes, Sir G. G.—Recording the Direct Intensity of Solar Radiation	15	0	0
*Lodge, Professor O. J.—National Physical Laboratory	5	0	0

Chemistry and Mineralogy.

*Roscoe, Sir H.—Wave-length Tables of the Spectra of the Elements (renewed)	10	0	0
*Roberts-Austen, Professor—Analysis of Iron and Steel (renewed)	15	0	0
*Thorpe, Professor T. E.—Action of Light upon Dyed Colours	5	0	0

Geology.

*Hull, Professor E.—Erratic Blocks	15	0	0
*Wiltshire, Rev. T.—Fossil Phyllopoda	5	0	0
*Geikie, Professor J.—Photographs of Geological Interest (renewed)	10	0	0
*Horne, Mr. J.—Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
*Traquair, Dr. R. H.—Eurypterids of the Pentland Hills	5	0	0
Woodward, Mr. H. B.—New Sections of Stonesfield Slate	25	0	0
*Symons, Mr. G. J.—Observations on Earth Tremors	50	0	0
Tiddeman, Mr. R. H.—Exploration of Calf Hole Cave	5	0	0
Carried forward	£235	0	0

* Reappointed.

	£	s.	d.
Brought forward	235	0	0
Biology.			
*Sclater, Dr. P. L.—Table at the Naples Zoological Station	100	0	0
*Lankester, Professor E. R.—Table at the Plymouth Biological Laboratory (renewed)	15	0	0
*Newton, Professor A.—Zoology of Sandwich Islands	100	0	0
*Herdman, Professor W. A.—Zoology of the Irish Sea	40	0	0
Schäfer, Professor E. A.—Structure and Function of the Mammalian Heart	10	0	0
Geography.			
*Ravenstein, Mr. E. G.—Climatology and Hydrography of Tropical Africa	10	0	0
Markham, Mr. Clements R.—Observations in South Georgia	50	0	0
Seebohm, Mr. H.—Exploration in Arabia	30	0	0
Economic Science and Statistics.			
*Cunningham, Professor W.—Methods of Economic Training	10	0	0
Anthropology.			
*Flower, Sir W. H.—Anthropometric Laboratory Statistics	5	0	0
*Brabrook, Mr. E. W.—Ethnographical Survey of United Kingdom	10	0	0
Munro, Dr. R.—The Lake Village at Glastonbury	40	0	0
Cleland, Professor J.—Anthropometrical Measurements in Schools	5	0	0
*Galton, Sir D.—Mental and Physical Condition of Children	20	0	0
*Garson, Dr. J. G.—Corresponding Societies Committee	25	0	0
	£705	0	0

* Reappointed.

The Annual Meeting in 1894.

The Meeting at Oxford will commence on Wednesday, August 8.

Place of Meeting in 1895.

The Annual Meeting of the Association will be held at Ipswich.

General Statement of Sums which have been paid on account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£435	0	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	93	3	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£922	12	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
	£932	2	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth, &c.	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-iron Experiments	103	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	171	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	166	16	6
Animal Secretions	10	10	0
Steam Engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0

	£	s.	d.
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	6
Railway Sections	38	1	0
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Co-operation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture, and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Co-operation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East Coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment at Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology......1842	0	10	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	0
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	0	0
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment at Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£831	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	5	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	8
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogue of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining the Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on Account of Anemometrical Observations	13	9	0
	£159	19	6

1850.	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

1851.	£	s.	d.
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7

1852.	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7

1853.	£	s.	d.
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0

1854.	£	s.	d.
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7

1855.	£	s.	d.
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4

1856.	£	s.	d.
Maintaining the Establishment at Kew Observatory:— 1854.........£ 75 0 0; 1855.........£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	0
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9

1857.	£	s.	d.
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0

	£	s.	d.
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-boats	5	0	0
	£507	15	4

1858.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2

1859.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1

1860.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£766	19	6

1861.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860......£50 0 0; 1861......£22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahagow	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	10
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. of America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connection of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0

	£	s.	d.
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east Coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
Electrical Construction and Distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-gauges	19	15	8
Cast-iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0
Rain-gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	10
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	29	0	0

	£	s.	d.
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c., Leaf-beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyl and Methyl Series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl Series	25	0	0
Mercury and Bile	25	0	0
Organic Remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic Remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical Nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron, &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0

	£	s.	d.
Mountain Limestone Fossils	25	0	0
Utilisation of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Coral Sections, for Photographing	20	0	0
Bagshot Leaf-beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.

	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetisation of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-West of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain Limestone-corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High Temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-measures	7	15	0
	£1151	16	0

1875.

	£	s.	d.
Elliptic Functions	100	0	0
Magnetisation of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0

	£	s.	d.
Specific Volume of Liquids...	25	0	0
Estimation of Potash and Phosphoric Acid...............	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations ...	100	0	0
Kent's Cavern Exploration...	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record...............	100	0	0
Instructions for Travellers ...	20	0	0
Intestinal Secretions	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

1876.

	£	s.	d.
Printing Mathematical Tables	159	4	2
British Rainfall..................	100	0	0
Ohm's Law.........................	9	15	0
Tide Calculating Machine ...	200	0	0
Specific Volume of Liquids...	25	0	0
Isomeric Cresols	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate..........................	5	0	0
Estimation of Potash and Phosphoric Acid..............	13	0	0
Exploration of Victoria Cave, Settle	100	0	0
Geological Record..............	100	0	0
Kent's Cavern Exploration...	100	0	0
Thermal Conductivities of Rocks	10	0	0
Underground Waters	10	0	0
Earthquakes in Scotland......	1	10	0
Zoological Record..............	100	0	0
Close Time	5	0	0
Physiological Action of Sound	25	0	0
Zoological Station..............	75	0	0
Intestinal Secretions	15	0	0
Physical Characters of Inhabitants of British Isles......	13	15	0
Measuring Speed of Ships ...	10	0	0
Effect of Propeller on turning of Steam-vessels	5	0	0
	£1092	4	2

1877.

	£	s.	d.
Liquid Carbonic Acids in Minerals	20	0	0
Elliptic Functions	250	0	0
Thermal Conductivity of Rocks	9	11	7
Zoological Record...............	100	0	0
Kent's Cavern	100	0	0
Zoological Station at Naples	75	0	0
Luminous Meteors	30	0	0
Elasticity of Wires	100	0	0
Dipterocarpæ, Report on... ..	20	0	0
Mechanical Equivalent of Heat..............................	35	0	0
Double Compounds of Cobalt and Nickel	8	0	0
Underground Temperatures	50	0	0
Settle Cave Exploration	100	0	0
Underground Waters in New Red Sandstone	10	0	0
Action of Ethyl Bromobutyrate on Ethyl Sodaceto-acetate	10	0	0
British Earthworks	25	0	0
Atmospheric Elasticity in India	15	0	0
Development of Light from Coal-gas	20	0	0
Estimation of Potash and Phosphoric Acid...............	1	18	0
Geological Record...............	100	0	0
Anthropometric Committee	34	0	0
Physiological Action of Phosphoric Acid, &c................	15	0	0
	£1128	9	7

1878.

	£	s.	d.
Exploration of Settle Caves	100	0	0
Geological Record...............	100	0	0
Investigation of Pulse Phenomena by means of Syphon Recorder	10	0	0
Zoological Station at Naples	75	0	0
Investigation of Underground Waters..........................	15	0	0
Transmission of Electrical Impulses through Nerve Structure.........................	30	0	0
Calculation of Factor Table for 4th Million	100	0	0
Anthropometric Committee...	66	0	0
Chemical Composition and Structure of less-known Alkaloids.........................	25	0	0
Exploration of Kent's Cavern	50	0	0
Zoological Record	100	0	0
Fermanagh Caves Exploration	15	0	0
Thermal Conductivity of Rocks	4	16	6
Luminous Meteors...............	10	0	0
Ancient Earthworks	25	0	0
	£725	16	6

1879.

	£	s.	d.
Table at the Zoological Station, Naples	75	0	0
Miocene Flora of the Basalt of the North of Ireland ...	20	0	0
Illustrations for a Monograph on the Mammoth	17	0	0
Record of Zoological Literature	100	0	0
Composition and Structure of less-known Alkaloids	25	0	0

	£	s.	d.
Exploration of Caves in Borneo	50	0	0
Kent's Cavern Exploration	100	0	0
Record of the Progress of Geology	100	0	0
Fermanagh Caves Exploration	5	0	0
Electrolysis of Metallic Solutions and Solutions of Compound Salts	25	0	0
Anthropometric Committee	50	0	0
Natural History of Socotra	100	0	0
Calculation of Factor Tables for 5th and 6th Millions	150	0	0
Circulation of Underground Waters	10	0	0
Steering of Screw Steamers	10	0	0
Improvements in Astronomical Clocks	30	0	0
Marine Zoology of South Devon	20	0	0
Determination of Mechanical Equivalent of Heat	12	15	6
Specific Inductive Capacity of Sprengel Vacuum	40	0	0
Tables of Sun-heat Coefficients	30	0	0
Datum Level of the Ordnance Survey	10	0	0
Tables of Fundamental Invariants of Algebraic Forms	36	14	9
Atmospheric Electricity Observations in Madeira	15	0	0
Instrument for Detecting Fire-damp in Mines	22	0	0
Instruments for Measuring the Speed of Ships	17	1	8
Tidal Observations in the English Channel	10	0	0
	£1080	11	11

1880.

	£	s.	d.
New Form of High Insulation Key	10	0	0
Underground Temperature	10	0	0
Determination of the Mechanical Equivalent of Heat	8	5	0
Elasticity of Wires	50	0	0
Luminous Meteors	30	0	0
Lunar Disturbance of Gravity	30	0	0
Fundamental Invariants	8	5	0
Laws of Water Friction	20	0	0
Specific Inductive Capacity of Sprengel Vacuum	20	0	0
Completion of Tables of Sun-heat Coefficients	50	0	0
Instrument for Detection of Fire-damp in Mines	10	0	0
Inductive Capacity of Crystals and Paraffines	4	17	7
Report on Carboniferous Polyzoa	10	0	0
Caves of South Ireland	10	0	0
Viviparous Nature of Ichthyosaurus	10	0	0
Kent's Cavern Exploration	50	0	0
Geological Record	100	0	0
Miocene Flora of the Basalt of North Ireland	15	0	0
Underground Waters of Permian Formations	5	0	0
Record of Zoological Literature	100	0	0
Table at Zoological Station at Naples	75	0	0
Investigation of the Geology and Zoology of Mexico	50	0	0
Anthropometry	50	0	0
Patent Laws	5	0	0
	£731	7	7

1881.

	£	s.	d.
Lunar Disturbance of Gravity	30	0	0
Underground Temperature	20	0	0
Electrical Standards	25	0	0
High Insulation Key	5	0	0
Tidal Observations	10	0	0
Specific Refractions	7	3	1
Fossil Polyzoa	10	0	0
Underground Waters	10	0	0
Earthquakes in Japan	25	0	0
Tertiary Flora	20	0	0
Scottish Zoological Station	50	0	0
Naples Zoological Station	75	0	0
Natural History of Socotra	50	0	0
Anthropological Notes and Queries	9	0	0
Zoological Record	100	0	0
Weights and Heights of Human Beings	30	0	0
	£476	3	1

1882.

	£	s.	d.
Exploration of Central Africa	100	0	0
Fundamental Invariants of Algebraical Forms	76	1	11
Standards for Electrical Measurements	100	0	0
Calibration of Mercurial Thermometers	20	0	0
Wave-length Tables of Spectra of Elements	50	0	0
Photographing Ultra-violet Spark Spectra	25	0	0
Geological Record	100	0	0
Earthquake Phenomena of Japan	25	0	0
Conversion of Sedimentary Materials into Metamorphic Rocks	10	0	0
Fossil Plants of Halifax	15	0	0
Geological Map of Europe	25	0	0
Circulation of Underground Waters	15	0	0

	£	s.	d.
Tertiary Flora of North of Ireland	20	0	0
British Polyzoa	10	0	0
Exploration of Caves of South of Ireland	10	0	0
Exploration of Raygill Fissure	20	0	0
Naples Zoological Station ...	80	0	0
Albuminoid Substances of Serum	10	0	0
Elimination of Nitrogen by Bodily Exercise	50	0	0
Migration of Birds	15	0	0
Natural History of Socotra ...	100	0	0
Natural History of Timor-laut	100	0	0
Record of Zoological Literature	100	0	0
Anthropometric Committee...	50	0	0
	£1126	1	11

1883.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Isomeric Naphthalene Derivatives	15	0	0
Earthquake Phenomena of Japan	50	0	0
Fossil Plants of Halifax	20	0	0
British Fossil Polyzoa	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Erosion of Sea-coast of England and Wales	10	0	0
Circulation of Underground Waters	15	0	0
Geological Record	50	0	0
Exploration of Caves in South of Ireland	10	0	0
Zoological Literature Record	100	0	0
Migration of Birds	20	0	0
Zoological Station at Naples	80	0	0
Scottish Zoological Station...	25	0	0
Elimination of Nitrogen by Bodily Exercise	38	3	3
Exploration of Mount Kilima-njaro	500	0	0
Investigation of Loughton Camp	10	0	0
Natural History of Timor-laut	50	0	0
Screw Gauges	5	0	0
	£1083	3	3

1884.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Collecting and Investigating Meteoric Dust	20	0	0
Meteorological Observatory at Chepstow	25	0	0
Tidal Observations	10	0	0
Ultra Violet Spark Spectra ...	8	4	0
Earthquake Phenomena of Japan	75	0	0
Fossil Plants of Halifax	15	0	0
Fossil Polyzoa	10	0	0
Erratic Blocks of England ...	10	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Circulation of Underground Waters	5	0	0
International Geological Map	20	0	0
Bibliography of Groups of Invertebrata	50	0	0
Natural History of Timor-laut	50	0	0
Naples Zoological Station ...	80	0	0
Exploration of Mount Kilima-njaro, East Africa	500	0	0
Migration of Birds	20	0	0
Coagulation of Blood	100	0	0
Zoological Literature Record	100	0	0
Anthropometric Committee...	10	0	0
	£1173	4	0

1885.

	£	s.	d.
Synoptic Chart of Indian Ocean	50	0	0
Reduction of Tidal Observations	10	0	0
Calculating Tables in Theory of Numbers	100	0	0
Meteorological Observations on Ben Nevis	50	0	0
Meteoric Dust	70	0	0
Vapour Pressures, &c., of Salt Solutions	25	0	0
Physical Constants of Solutions	20	0	0
Volcanic Phenomena of Vesuvius	25	0	0
Raygill Fissure	15	0	0
Earthquake Phenomena of Japan	70	0	0
Fossil Phyllopoda of Palæozoic Rocks	25	0	0
Fossil Plants of British Tertiary and Secondary Beds .	50	0	0
Geological Record	50	0	0
Circulation of Underground Waters	10	0	0
Naples Zoological Station ...	100	0	0
Zoological Literature Record.	100	0	0
Migration of Birds	30	0	0
Exploration of Mount Kilima-njaro	25	0	0
Recent Polyzoa	10	0	0
Marine Biological Station at Granton	100	0	0
Biological Stations on Coasts of United Kingdom	150	0	0
Exploration of New Guinea...	200	0	0
Exploration of Mount Roraima	100	0	0
	£1385	0	0

1886.	£	s.	d.
Electrical Standards	40	0	0
Solar Radiation	9	10	6
Tidal Observations	50	0	0
Magnetic Observations	10	10	0
Meteorological Observations on Ben Nevis	100	0	0
Physical and Chemical Bearings of Electrolysis	20	0	0
Chemical Nomenclature	5	0	0
Fossil Plants of British Tertiary and Secondary Beds	20	0	0
Exploration of Caves in North Wales	25	0	0
Volcanic Phenomena of Vesuvius	30	0	0
Geological Record	100	0	0
Fossil Phyllopoda of Palæozoic Rocks	15	0	0
Zoological Literature Record	100	0	0
Marine Biological Station at Granton	75	0	0
Naples Zoological Station	50	0	0
Researches in Food-Fishes and Invertebrata at St. Andrews	75	0	0
Migration of Birds	30	0	0
Secretion of Urine	10	0	0
Exploration of New Guinea	150	0	0
Regulation of Wages under Sliding Scales	10	0	0
Prehistoric Race in Greek Islands	20	0	0
North-Western Tribes of Canada	50	0	0
	£995	0	6

1887.	£	s.	d.
Solar Radiation	18	10	0
Electrolysis	30	0	0
Ben Nevis Observatory	75	0	0
Standards of Light (1886 grant)	20	0	0
Standards of Light (1887 grant)	10	0	0
Harmonic Analysis of Tidal Observations	15	0	0
Magnetic Observations	26	2	0
Electrical Standards	50	0	0
Silent Discharge of Electricity	20	0	0
Absorption Spectra	40	0	0
Nature of Solution	20	0	0
Influence of Silicon on Steel	30	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Volcanic Phenomena of Japan (1886 grant)	50	0	0
Volcanic Phenomena of Japan (1887 grant)	50	0	0
Exploration of Cae Gwyn Cave, North Wales	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	20	0	0
Coal Plants of Halifax	25	0	0
Microscopic Structure of the Rocks of Anglesey	10	0	0
Exploration of the Eocene Beds of the Isle of Wight	20	0	0
Circulation of Underground Waters	5	0	0
'Manure' Gravels of Wexford	10	0	0
Provincial Museum Reports	5	0	0
Investigation of Lymphatic System	25	0	0
Naples Biological Station	100	0	0
Plymouth Biological Station	50	0	0
Granton Biological Station	75	0	0
Zoological Record	100	0	0
Flora of China	75	0	0
Flora and Fauna of the Cameroons	75	0	0
Migration of Birds	30	0	0
Bathy-hypsographical Map of British Isles	7	6	0
Regulation of Wages	10	0	0
Prehistoric Race of Greek Islands	20	0	0
Racial Photographs, Egyptian	20	0	0
	£1186	18	0

1888.	£	s.	d.
Ben Nevis Observatory	150	0	0
Electrical Standards	2	6	4
Magnetic Observations	15	0	0
Standards of Light	79	2	3
Electrolysis	30	0	0
Uniform Nomenclature in Mechanics	10	0	0
Silent Discharge of Electricity	9	11	10
Properties of Solutions	25	0	0
Influence of Silicon on Steel	20	0	0
Methods of Teaching Chemistry	10	0	0
Isomeric Naphthalene Derivatives	25	0	0
Action of Light on Hydracids	20	0	0
Sea Beach near Bridlington	20	0	0
Geological Record	50	0	0
Manure Gravels of Wexford	10	0	0
Erosion of Sea Coasts	10	0	0
Circulation of Underground Waters	5	0	0
Palæontographical Society	50	0	0
Pliocene Fauna of St. Erth	50	0	0
Carboniferous Flora of Lancashire and West Yorkshire	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Zoology and Botany of West Indies	100	0	0
Flora of Bahamas	100	0	0
Development of Fishes—St. Andrews	50	0	0
Marine Laboratory, Plymouth	100	0	0
Migration of Birds	30	0	0
Flora of China	75	0	0

	£	s.	d.
Naples Zoological Station ...	100	0	0
Lymphatic System	25	0	0
Biological Station at Granton	50	0	0
Peradeniya Botanical Station	50	0	0
Development of Teleostei ...	15	0	0
Depth of Frozen Soil in Polar Regions	5	0	0
Precious Metals in Circulation	20	0	0
Value of Monetary Standard	10	0	0
Effect of Occupations on Physical Development...........	25	0	0
North-Western Tribes of Canada	100	0	0
Prehistoric Race in Greek Islands........................	20	0	0
	£1511	0	5

1889.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards...........	75	0	0
Electrolysis........................	20	0	0
Observations on Surface Water Temperature	30	0	0
Silent Discharge of Electricity on Oxygen	6	4	8
Methods of teaching Chemistry	10	0	0
Action of Light on Hydracids	10	0	0
Geological Record..............	80	0	0
Volcanic Phenomena of Japan	25	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of Palæozoic Rocks	20	0	0
Higher Eocene Beds of Isle of Wight	15	0	0
West Indian Explorations ...	100	0	0
Flora of China	25	0	0
Naples Zoological Station ...	100	0	0
Physiology of Lymphatic System	25	0	0
Experiments with a Tow-net	5	16	3
Natural History of Friendly Islands...........................	100	0	0
Geology and Geography of Atlas Range...	100	0	0
Action of Waves and Currents in Estuaries by means of Working Models	100	0	0
North-Western Tribes of Canada	150	0	0
Characteristics of Nomad Tribes of Asia Minor.........	30	0	0
Corresponding Societies	20	0	0
Marine Biological Association	200	0	0
Bath 'Baths Committee' for further Researches	100	0	0
	£1417	0	11

1890.

	£	s.	d.
Electrical Standards...........	12	17	0
Electrolysis	5	0	0
Electro-optics.....................	50	0	0
Calculating Mathematical Tables	25	0	0
Volcanic and Seismological Phenomena of Japan	75	0	0
Pellian Equation Tables	15	0	0
Properties of Solutions	10	0	0
International Standard for the Analysis of Iron and Steel	10	0	0
Influence of the Silent Discharge of Electricity on Oxygen	5	0	0
Methods of teaching Chemistry	10	0	0
Recording Results of Water Analysis	4	1	0
Oxidation of Hydracids in Sunlight	15	0	0
Volcanic Phenomena of Vesuvius	20	0	0
Fossil Phyllopoda of the Palæozoic Rocks.................	10	0	0
Circulation of Underground Waters..........................	5	0	0
Excavations at Oldbury Hill	15	0	0
Cretaceous Polyzoa	10	0	0
Geological Photographs	7	14	11
Lias Beds of Northamptonshire	25	0	0
Botanical Station at Peradeniya	25	0	0
Experiments with a Tow-net	4	3	9
Naples Zoological Station ...	100	0	0
Zoology and Botany of the West India Islands	100	0	0
Marine Biological Association	30	0	0
Action of Waves and Currents in Estuaries	150	0	0
Graphic Methods in Mechanical Science	11	0	0
Anthropometric Calculations	5	0	0
Nomad Tribes of Asia Minor	25	0	0
Corresponding Societies	20	0	0
	£799	16	8

1891.

	£	s.	d.
Ben Nevis Observatory.........	50	0	0
Electrical Standards...........	100	0	0
Electrolysis.......................	5	0	0
Seismological Phenomena of Japan	10	0	0
Variations of Temperature in Lakes	20	0	0
Photographs of Meteorological Phenomena....................	5	0	0
Discharge of Electricity from Points	10	0	0
Ultra Violet Rays of Solar Spectrum	50	0	0
International Standard for the Analysis of Iron and Steel............................	10	0	0

	£	s.	d.
Isomeric Naphthalene Derivatives	25	0	0
Formation of Haloids	25	0	0
Action of Light on Dyes	17	10	0
Geological Record	100	0	0
Volcanic Phenomena of Vesuvius	10	0	0
Fossil Phyllopoda	10	0	0
Photographs of Geological Interest	9	5	0
Lias Beds of Northamptonshire	25	0	0
Registration of Type-Specimens of British Fossils	5	5	0
Investigation of Elbolton Cave	25	0	0
Botanical Station at Peradeniya	50	0	0
Experiments with a Tow-net	40	0	0
Marine Biological Association at Plymouth	12	10	0
Disappearance of Native Plants	5	0	0
Action of Waves and Currents in Estuaries	125	0	0
Anthropometric Calculations	10	0	0
New Edition of 'Anthropological Notes and Queries'	50	0	0
North-Western Tribes of Canada	200	0	0
Corresponding Societies	25	0	0
	£1,029	10	0

1892.

	£	s.	d.
Meteorological Observations on Ben Nevis	50	0	0
Photographs of Meteorological Phenomena	15	0	0
Pellian Equation Tables	10	0	0
Discharge of Electricity from Points	50	0	0
Seismological Phenomena of Japan	10	0	0
Formation of Haloids	12	0	0
Properties of Solutions	10	0	0
Action of Light on Dyed Colours	10	0	0
Erratic Blocks	15	0	0
Photographs of Geological Interest	20	0	0
Underground Waters	10	0	0
Investigation of Elbolton Cave	25	0	0
Excavations at Oldbury Hill	10	0	0
Cretaceous Polyzoa	10	0	0
Table at Naples Zoological Station	100	0	0
Table at Plymouth Biological Laboratory	17	10	0
Improving a Deep-sea Tow-net	40	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	100	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Anthropometric Laboratory	5	0	0
Anthropological Notes and Queries	20	0	0
Prehistoric Remains in Mashonaland	50	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies	25	0	0
	£864	10	0

1893.

	£	s.	d.
Electrical Standards	25	0	0
Meteorological Observations on Ben Nevis	150	0	0
Tables of Mathematical Functions	15	0	0
Recording the Direct Intensity of Solar Radiation	2	8	6
Magnetic Work at the Falmouth Observatory	25	0	0
Isomeric Naphthalene Derivatives	20	0	0
Erratic Blocks	10	0	0
Fossil Phyllopoda	5	0	0
Underground Waters	5	0	0
Shell-bearing Deposits at Clava, Chapelhall, &c.	20	0	0
Eurypterids of the Pentland Hills	10	0	0
Table at the Naples Zoological Station	100	0	0
Table at the Plymouth Biological Laboratory	30	0	0
Fauna of Sandwich Islands	100	0	0
Zoology and Botany of West India Islands	50	0	0
Exploration of Irish Sea	30	0	0
Physiological Action of Oxygen in Asphyxia	20	0	0
Index of Genera and Species of Animals	20	0	0
Exploration of Karakoram Mountains	50	0	0
Scottish Place-names	7	0	0
Climatology and Hydrography of Tropical Africa	50	0	0
Methods of Economic Training	3	7	0
Anthropometric Laboratory	5	0	0
Exploration of Ancient Remains in Abyssinia	25	0	0
North-Western Tribes of Canada	100	0	0
Corresponding Societies Committee	30	0	0
	£907	15	6

General Meetings.

On Wednesday, September 13, at 8 P.M., in the Albert Hall, Sir Archibald Geikie, LL.D., D.Sc., For.Sec.R.S., F.R.S.E., F.G.S., resigned the office of President to Professor J. S. Burdon Sanderson, M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., who took the Chair, and delivered an Address, for which see page 3.

On Thursday, September 14, at 8 P.M., a Soirée took place at the Castle.

On Friday, September 15, at 8.30 P.M., in the Albert Hall, Professor Arthur Smithells, B.Sc., delivered a discourse on 'Flame.'

On Monday, September 18, at 8.30 P.M., in the Albert Hall, Professor Victor Horsley, F.R.S., delivered a discourse on 'The Discovery of the Physiology of the Nervous System.'

On Tuesday, September 19, at 8 P.M., a Soirée took place at the Castle.

On Wednesday, September 20, at 2.30 P.M., in University College, the concluding General Meeting took place, when the Proceedings of the General Committee and the Grants of Money for Scientific Purposes were explained to the Members.

The Meeting was then adjourned to Oxford. [The Meeting is appointed to commence on Wednesday, August 8, 1894.]

PRESIDENT'S ADDRESS.

ADDRESS

BY

J. S. BURDON SANDERSON,

M.A., M.D., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford,

PRESIDENT.

We are assembled this evening as representatives of the sciences—men and women who seek to advance knowledge by scientific methods. The common ground on which we stand is that of belief in the paramount value of the end for which we are striving, of its inherent power to make men wiser, happier, and better; and our common purpose is to strengthen and encourage one another in our efforts for its attainment. We have come to learn what progress has been made in departments of knowledge which lie outside of our own special scientific interests and occupations, to widen our views, and to correct whatever misconceptions may have arisen from the necessity which limits each of us to his own field of study; and, above all, we are here for the purpose of bringing our divided energies into effectual and combined action.

Probably few of the members of the Association are fully aware of the influence which it has exercised during the last half-century and more in furthering the scientific development of this country. Wide as is the range of its activity, there has been no great question in the field of scientific inquiry which it has failed to discuss; no important line of investigation which it has not promoted; no great discovery which it has not welcomed. After more than sixty years of existence it still finds itself in the energy of middle life, looking back with satisfaction to what it has accomplished in its youth, and forward to an even more efficient future. One of the first of the national associations which exist in different countries for the advancement of science, its influence has been more felt than that of its successors because it is more wanted. The wealthiest

country in the world, which has profited more—vastly more—by science than any other, England stands alone in the discredit of refusing the necessary expenditure for its development, and cares not that other nations should reap the harvest for which her own sons have laboured.

It is surely our duty not to rest satisfied with the reflection that England in the past has accomplished so much, but rather to unite and agitate in the confidence of eventual success. It is not the fault of governments, but of the nation, that the claims of science are not recognised. We have against us an overwhelming majority of the community, not merely of the ignorant, but of those who regard themselves as educated, who value science only in so far as it can be turned into money; for we are still in great measure—in greater measure than any other—a nation of shopkeepers. Let us who are of the minority—the remnant who believe that truth is in itself of supreme value, and the knowledge of it of supreme utility—do all that we can to bring public opinion to our side, so that the century which has given Young, Faraday, Lyell, Darwin, Maxwell, and Thomson to England, may before it closes see us prepared to take our part with other countries in combined action for the full development of natural knowledge.

Last year the necessity of an imperial observatory for physical science was, as no doubt many are aware, the subject of a discussion in Section A, which derived its interest from the number of leading physicists who took part in it, and especially from the presence and active participation of the distinguished man who is at the head of the National Physical Laboratory at Berlin. The equally pressing necessity for a central institution for chemistry, on a scale commensurate with the practical importance of that science, has been insisted upon in this Association and elsewhere by distinguished chemists. As regards biology I shall have a word to say in the same direction this evening. Of these three requirements it may be that the first is the most pressing. If so, let us all, whatever branch of science we represent, unite our efforts to realise it, in the assurance that if once the claim of science to liberal public support is admitted, the rest will follow.

In selecting a subject on which to address you this evening I have followed the example of my predecessors in limiting myself to matters more or less connected with my own scientific occupations, believing that in discussing what most interests myself I should have the best chance of interesting you. The circumstance that at the last meeting of the British Association in this town, Section D assumed for the first time the title which it has since held, that of the Section of Biology, suggested to me that I might take the word 'biology' as my starting-point, giving you some account of its origin and first use, and of the relations which subsist between biology and other branches of natural science.

Origin and Meaning of the Term 'Biology.'

The word 'biology,' which is now so familiar as comprising the sum of the knowledge which has as yet been acquired concerning living nature, was unknown until after the beginning of the present century. The term was first employed by Treviranus, who proposed to himself as a life-task the development of a new science, the aim of which should be to study the forms and phenomena of life, its origin and the conditions and laws of its existence, and embodied what was known on these subjects in a book of seven volumes, which he entitled 'Biology, or the Philosophy of Living Nature.' For its construction the material was very scanty, and was chiefly derived from the anatomists and physiologists. For botanists were entirely occupied in completing the work which Linnæus had begun, and the scope of zoology was in like manner limited to the description and classification of animals. It was a new thing to regard the study of living nature as a science by itself, worthy to occupy a place by the side of natural philosophy, and it was therefore necessary to vindicate its claim to such a position. Treviranus declined to found this claim on its useful applications to the arts of agriculture and medicine, considering that to regard any subject of study in relation to our bodily wants—in other words to utility—was to narrow it, but dwelt rather on its value as a discipline and on its surpassing interest. He commends biology to his readers as a study which, above all others, 'nourishes and maintains the taste for simplicity and nobleness; which affords to the intellect ever new material for reflection, and to the imagination an inexhaustible source of attractive images.'

Being himself a mathematician as well as a naturalist, he approaches the subject both from the side of natural philosophy and from that of natural history, and desires to found the new science on the fundamental distinction between living and non-living material. In discussing this distinction, he takes as his point of departure the constancy with which the activities which manifest themselves in the universe are balanced, emphasising the impossibility of excluding from that balance the vital activities of plants and animals. The difference between vital and physical processes he accordingly finds, not in the nature of the processes themselves, but in their co-ordination; that is, in their adaptedness to a given purpose, and to the peculiar and special relation in which the organism stands to the external world. All of this is expressed in a proposition difficult to translate into English, in which he defines life as consisting in the reaction of the organism to external influences, and contrasts the uniformity of vital reactions with the variety of their exciting causes.[1]

[1] 'Leben besteht in der Gleichförmigkeit der Reaktionen bei ungleichförmigen Einwirkungen der Aussenwelt.'—Treviranus, *Biologie oder Philosophie der lebenden Natur*, Göttingen, 1802, vol. i. p. 83.

The purpose which I have in view in taking you back as I have done to the beginning of the century is not merely to commemorate the work done by the wonderfully acute writer to whom we owe the first scientific conception of the science of life as a whole, but to show that this conception, as expressed in the definition I have given you as its foundation, can still be accepted as true. It suggests the *idea of organism* as that to which all other biological ideas must relate. It also suggests, although perhaps it does not express it, that *action* is not an attribute of the organism but of its essence—that if, on the one hand, protoplasm is the basis of life, life is the basis of protoplasm. Their relations to each other are reciprocal. We think of the visible structure only in connection with the invisible process. The definition is also of value as indicating at once the two lines of inquiry into which the science has divided by the natural evolution of knowledge. These two lines may be easily educed from the general principle from which Treviranus started, according to which it is the fundamental characteristic of the organism that all that goes on in it is to the advantage of the whole. I need scarcely say that this fundamental conception of organism has at all times presented itself to the minds of those who have sought to understand the distinction between living and non-living. Without going back to the true father and founder of biology, Aristotle, we may recall with interest the language employed in relation to it by the physiologists of three hundred years ago. It was at that time expressed by the term *consensus partium*—which was defined as the concurrence of parts in action, of such a nature that each does *quod suum est*, all combining to bring about one effect 'as if they had been in secret council,' but at the same time *constanti quadam naturæ lege*.[1] Professor Huxley has made familiar to us how a century later Descartes imagined to himself a mechanism to carry out this *consensus*, based on such scanty knowledge as was then available of the structure of the nervous system. The discoveries of the early part of the present century relating to reflex action and the functions of sensory and motor nerves, served to realise in a wonderful way his anticipations as to the channels of influence, afferent and efferent, by which the *consensus* is maintained; and in recent times (as we hope to learn from Professor Horsley's lecture on the physiology of the nervous system) these channels have been investigated with extraordinary minuteness and success.

Whether with the old writers we speak about *consensus*, with Treviranus about *adaptation*, or are content to take *organism* as our point of departure, it means that, regarding a plant or an animal as an organism, we concern ourselves primarily with its activities or, to use the word which best expresses it, its energies. Now the first thing that strikes us in beginning to think about the activities of an organism is that they are naturally

[1] Bausner, *De Consensu Partium Humani Corporis*, Amst., 1556, Præf. ad lectorem, p. 4.

distinguishable into two kinds, according as we consider the action of the whole organism in its relation to the external world or to other organisms, or the action of the parts or organs in their relation to each other. The distinction to which we are thus led between the *internal* and *external* relations of plants and animals has of course always existed, but has only lately come into such prominence that it divides biologists more or less completely into two camps—on the one hand those who make it their aim to investigate the actions of the organism and its parts by the accepted methods of physics and chemistry, carrying this investigation as far as the conditions under which each process manifests itself will permit; on the other those who interest themselves rather in considering the place which each organism occupies, and the part which it plays in the economy of nature. It is apparent that the two lines of inquiry, although they equally relate to what the organism *does*, rather than to what it *is*, and therefore both have equal right to be included in the one great science of life, or biology, yet lead in directions which are scarcely even parallel. So marked, indeed, is the distinction, that Professor Haeckel some twenty years ago proposed to separate the study of organisms with reference to their place in nature under the designation of 'œcology,' defining it as comprising 'the relations of the animal to its organic as well as to its inorganic environment, particularly its friendly or hostile relations to those animals or plants with which it comes into direct contact.'[1] Whether this term expresses it or not, the distinction is a fundamental one. Whether with the œcologist we regard the organism in relation to the world, or with the physiologist as a wonderful complex of vital energies, the two branches have this in common, that both studies fix their attention, not on stuffed animals, butterflies in cases, or even microscopical sections of the animal or plant body—all of which relate to the framework of life—but on life itself.

The conception of biology which was developed by Treviranus as far as the knowledge of plants and animals which then existed rendered possible, seems to me still to express the scope of the science. I should have liked, had it been within my power, to present to you both aspects of the subject in equal fulness; but I feel that I shall best profit by the present opportunity if I derive my illustrations chiefly from the division of biology to which I am attached—that which concerns the *internal* relations of the organism, it being my object not to specialise in either direction, but, as Treviranus desired to do, to regard biology as part—surely a very important part—of the great science of nature.

The origin of life, the first transition from non-living to living, is a

[1] These he identifies with 'those complicated mutual relations which Darwin designates as conditions of the struggle for existence.' Along with chorology—the distribution of animals—œcology constitutes what he calls *Relations-Physiologie*. Haeckel, 'Entwickelungsgang u. Aufgaben der Zoologie,' *Jenaische Zeitschr.*, vol. v. 1869, p. 353.

riddle which lies outside of our scope. No seriously-minded person, however, doubts that organised nature as it now presents itself to us has become what it is by a process of gradual perfecting or advancement, brought about by the elimination of those organisms which failed to obey the fundamental principle of adaptation which Treviranus indicated. Each step, therefore, in this evolution is a reaction to external influences, the motive of which is essentially the same as that by which from moment to moment the organism governs itself. And the whole process is a necessary outcome of the fact that those organisms are most prosperous which look best after their own welfare. As in that part of biology which deals with the internal relations of the organism, the interest of the individual is in like manner the sole motive by which every energy is guided. We may take what Treviranus called *selfish* adaptation — *Zweckmässigkeit für sich selber*—as a connecting link between the two branches of biological study. Out of this relation springs another which I need not say was not recognised until after the Darwinian epoch—that, I mean, which subsists between the two evolutions, that of the race and that of the individual. Treviranus, no less distinctly than his great contemporary Lamarck, was well aware that the affinities of plants and animals must be estimated according to their developmental value, and consequently that classification must be founded on development; but it occurred to no one what the real link was between descent and development; nor was it, indeed, until several years after the publication of the 'Origin' that Haeckel enunciated that 'biogenetic law' according to which the development of any individual organism is but a memory, a recapitulation by the individual of the development of the race—of the process for which Fritz Müller had coined the excellent word 'phylogenesis'; and that each stage of the former is but a transitory reappearance of a bygone epoch in its ancestral history. If, therefore, we are right in regarding ontogenesis as dependent on phylogenesis, the origin of the former must correspond with that of the latter; that is, on the power which the race or the organism at every stage of its existence possesses of profiting by every condition or circumstance for its own advancement.

From the short summary of the connection between different parts of our science you will see that biology naturally falls into three divisions, and these are even more sharply distinguished by their methods than by their subjects; namely, *Physiology*, of which the methods are entirely experimental; *Morphology*, the science which deals with the forms and structure of plants and animals, and of which it may be said that the body is anatomy, the soul, development; and finally *Œcology*, which uses all the knowledge it can obtain from the other two, but chiefly rests on the exploration of the endless varied phenomena of animal and plant life as they manifest themselves under natural conditions. This last branch of biology—the science which concerns itself with the external relations of

plants and animals to each other, and to the past and present conditions of their existence—is by far the most attractive. In it those qualities of mind which especially distinguish the naturalist find their highest exercise, and it represents more than any other branch of the subject what Treviranus termed the 'philosophy of living nature.' Notwithstanding the very general interest which several of its problems excite at the present moment I do not propose to discuss any of them, but rather to limit myself to the humbler task of showing that the fundamental idea which finds one form of expression in the world of living beings regarded as a whole—the prevalence of the best—manifests itself with equal distinctness, and plays an equally essential part in the internal relations of the organism and in the great science which treats of them—Physiology.

Origin and Scope of Modern Physiology.

Just as there was no true philosophy of living nature until Darwin, we may with almost equal truth say that physiology did not exist as a science before Johannes Müller. For although the sum of his numerous achievements in comparative anatomy and physiology, notwithstanding their extraordinary number and importance, could not be compared for merit and fruitfulness with the one discovery which furnished the key to so many riddles, he, no less than Darwin, by his influence on his successors was the beginner of a new era.

Müller taught in Berlin from 1833 to 1857. During that time a gradual change was in progress in the way in which biologists regarded the fundamental problem of life. Müller himself, in common with Treviranus and all the biological teachers of his time, was a vitalist, *i.e.*, he regarded what was then called the *vis vitalis*—the *Lebenskraft*—as something capable of being correlated with the physical forces; and as a necessary consequence held that phenomena should be classified or distinguished, according to the forces which produced them, as vital or physical, and that all those processes—that is groups or series of phenomena in living organisms—for which, in the then very imperfect knowledge which existed, no obvious physical explanation could be found, were sufficiently explained when they were stated to be dependent on so-called vital laws. But during the period of Müller's greatest activity times were changing, and he was changing with them. During his long career as professor at Berlin he became more and more objective in his tendencies, and exercised an influence in the same direction on the men of the next generation, teaching them that it was better and more useful to observe than to philosophise; so that, although he himself is truly regarded as the last of the vitalists—for he was a vitalist to the last—his successors were adherents of what has been very inadequately designated the mechanistic view of the phenomena of life. The change thus brought about just before the middle of this century was a revolution. It was not a substitution of one point of view for another, but simply a frank aban-

donment of theory for fact, of speculation for experiment. Physiologists ceased to theorise because they found something better to do. May I try to give you a sketch of this era of progress?

Great discoveries as to the structure of plants and animals had been made in the course of the previous decade, those especially which had resulted from the introduction of the microscope as an instrument of research. By its aid Schwann had been able to show that all organised structures are built up of those particles of living substance which we now call cells, and recognise as the seats and sources of every kind of vital activity. Hugo Mohl, working in another direction, had given the name 'protoplasm' to a certain hyaline substance which forms the lining of the cells of plants, though no one as yet knew that it was the essential constituent of all living structures—the basis of life no less in animals than in plants. And, finally, a new branch of study—histology—founded on observations which the microscope had for the first time rendered possible, had come into existence. Bowman, one of the earliest and most successful cultivators of this new science, called it physiological anatomy,[1] and justified the title by the very important inferences as to the secreting function of epithelial cells and as to the nature of muscular contraction, which he deduced from his admirable anatomical researches. From structure to function, from microscopical observation to physiological experiment, the transition was natural. Anatomy was able to answer some questions, but asked many more. Fifty years ago physiologists had microscopes but had no laboratories. English physiologists—Bowman, Paget, Sharpey—were at the same time anatomists, and in Berlin Johannes Müller, along with anatomy and physiology, taught comparative anatomy and pathology. But soon that specialisation which, however much we may regret its necessity, is an essential concomitant of progress, became more and more inevitable. The structural conditions on which the processes of life depend had become, if not known, at least accessible to investigation; but very little indeed had been ascertained of the nature of the processes themselves—so little indeed that if at this moment we could blot from the records of physiology the whole of the information which had been acquired, say in 1840, the loss would be difficult to trace—not that the previously known facts were of little value, but because every fact of moment has since been subjected to experimental verification. It is for this reason that, without any hesitation, we accord to Müller and to his successors Brücke, du Bois-Reymond, Helmholtz, who were his pupils, and Ludwig, in Germany, and to Claude Bernard[2] in France, the title of founders of our science. For it is

[1] The first part of the *Physiological Anatomy* appeared in 1843. It was concluded in 1856.

[2] It is worthy of note that these five distinguished men were nearly contemporaries: Ludwig graduated in 1839, Bernard in 1843, the other three between those dates. Three survive—Helmholtz, Ludwig, du Bois-Reymond.

the work which they began at that remarkable time (1845–55), and which is now being carried on by their pupils or their pupils' pupils in England, America, France, Germany, Denmark, Sweden, Italy, and even in that youngest contributor to the advancement of science, Japan, that physiology has been gradually built up to whatever completeness it has at present attained.

What were the conditions which brought about this great advance which coincided with the middle of the century? There is but little difficulty in answering the question. I have already said that the change was not one of doctrine, but of method. There was, however, a leading idea in the minds of those who were chiefly concerned in bringing it about. That leading notion was, that, however complicated may be the conditions under which vital energies manifest themselves, they can be split into processes which are identical in nature with those of the non-living world, and, as a corollary to this, that the analysing of a vital process into its physical and chemical constituents, so as to bring these constituents into measurable relation with physical or chemical standards, is the only mode of investigating them which can lead to satisfactory results.

There were several circumstances which at that time tended to make the younger physiologists (and all of the men to whom I have just referred were then young) sanguine, perhaps too sanguine, in the hope that the application of experimental methods derived from the exact sciences would afford solutions of many physiological problems. One of these was the progress which had been made in the science of chemistry, and particularly the discovery that many of the compounds which before had been regarded as special products of vital processes could be produced in the laboratory, and the more complete knowledge which had been thereby acquired of their chemical constitutions and relations. In like manner, the new school profited by the advances which had been made in physics, partly by borrowing from the physical laboratory various improved methods of observing the phenomena of living beings, but chiefly in consequence of the direct bearing of the crowning discovery of that epoch (that of the conservation of energy) on the discussions which then took place as to the relations between vital and physical forces; in connection with which it may be noted that two of those who (along with Mr. Joule and your President at the last Nottingham meeting) took a prominent part in that discovery—Helmholtz and J. R. Mayer—were physiologists as much as they were physicists. I will not attempt even to enumerate the achievements of that epoch of progress. I may, however, without risk of wearying you, indicate the lines along which research at first proceeded, and draw your attention to the contrast between then and now. At present a young observer who is zealous to engage in research finds himself provided with the most elaborate means of investigation, the chief obstacle to his success being that the problems which have

been left over by his predecessors are of extreme difficulty, all of the easier questions having been worked out. There were then also difficulties, but of an entirely different kind. The work to be done was in itself easier, but the means for doing it were wanting, and every investigator had to depend on his own resources. Consequently the successful men were those who, in addition to scientific training, possessed the ingenuity to devise and the skill to carry out methods for themselves. The work by which du Bois-Reymond laid the foundation of animal electricity would not have been possible had not its author, besides being a trained physicist, known how to do as good work in a small room in the upper floor of the old University Building at Berlin as any which is now done in his splendid laboratory. Had Ludwig not possessed mechanical aptitude, in addition to scientific knowledge, he would have been unable to devise the apparatus by which he measured and recorded the variations of arterial pressure (1848), and verified the principles which Young had laid down thirty years before as to the mechanics of the circulation. Nor, lastly, could Helmholtz, had he not been a great deal more than a mere physiologist, have made those measurements of the time-relations of muscular and nervous responses to stimulation, which not only afford a solid foundation for all that has been done since in the same direction, but have served as models of physiological experiment, and as evidence that perfect work was possible and was done by capable men, even when there were no physiological laboratories.

Each of these examples relates to work done within a year or two of the middle of the century.[1] If it were possible to enter more fully on the scientific history of the time, we should, I think, find the clearest evidence, first, that the foundation was laid in anatomical discoveries, in which it is gratifying to remember that English anatomists (Allen Thomson, Bowman, Goodsir, Sharpey) took considerable share; secondly, that progress was rendered possible by the rapid advances which, during the previous decade, had been made in physics and chemistry, and the participation of physiology in the general awakening of the scientific spirit which these discoveries produced. I venture, however, to think that, notwithstanding the operation of these two causes, or rather combinations of causes, the development of our science would have been delayed had it not been for the exceptional endowments of the four or five young experimenters whose names I have mentioned, each of whom was capable of becoming a master in his own branch, and of guiding the future progress of inquiry.

Just as the affinities of an organism can be best learned from its development, so the scope of a science may be most easily judged of by

[1] The *Untersuchungen über thierische Electricität* appeared in 1848; Ludwig's researches on the circulation, which included the first description of the 'kymograph' and served as the foundation of the 'graphic method,' in 1847; Helmholtz's research on the propagation in motor nerves in 1851.

the tendencies which it exhibits in its origin. I wish now to complete the sketch I have endeavoured to give of the way in which physiology entered on the career it has since followed for the last half-century, by a few words as to the influence exercised on general physiological theory by the progress of research. We have seen that no real advance was made until it became possible to investigate the phenomena of life by methods which approached more or less closely to those of the physicist, in exactitude. The methods of investigation being physical or chemical, the organism itself naturally came to be considered as a complex of such processes, and nothing more. And in particular the idea of adaptation, which, as I have endeavoured to show, is not a consequence of organism, but its essence, was in great measure lost sight of. Not, I think, because it was any more possible than before to conceive of the organism otherwise than as a working together of parts for the good of the whole, but rather that, if I may so express it, the minds of men were so occupied with new facts that they had not time to elaborate theories. The old meaning of the term 'adaptation' as the equivalent of 'design' had been abandoned, and no new meaning had yet been given to it, and consequently the word 'mechanism' came to be employed as the equivalent of 'process,' as if the constant concomitance or sequence of two events was in itself a sufficient reason for assuming a mechanical relation between them. As in daily life so also in science, the misuse of words leads to misconceptions. To assert that the link between *a* and *b* is mechanical, for no better reason than that *b* always follows *a*, is an error of statement, which is apt to lead the incautious reader or hearer to imagine that the relation between *a* and *b* is understood, when in fact its nature may be wholly unknown. Whether or not at the time which we are considering, some physiological writers showed a tendency to commit this error, I do not think that it found expression in any generally accepted theory of life. It may, however, be admitted that the rapid progress of experimental investigation led to too confident anticipations, and that to some enthusiastic minds it appeared as if we were approaching within measurable distance of the end of knowledge. Such a tendency is, I think, a natural result of every signal advance. In an eloquent Harveian oration, delivered last autumn by Dr. Bridges, it was indicated how, after Harvey's great discovery of the circulation, men were too apt to found upon it explanations of all phenomena whether of health or disease, to such an extent that the practice of medicine was even prejudicially affected by it. In respect of its scientific importance the epoch we are considering may well be compared with that of Harvey, and may have been followed by an undue preference of the new as compared with the old, but no more permanent unfavourable results have shown themselves. As regards the science of medicine we need only remember that it was during the years between 1845 and 1860 that Virchow made those researches by which he brought the processes of disease into immediate relation with the normal processes

of cell-development and growth, and so, by making pathology a part of physiology, secured its subsequent progress and its influence on practical medicine. Similarly in physiology, the achievements of those years led on without any interruption or drawback to those of the following generation; while in general biology, the revolution in the mode of regarding the internal processes of the animal or plant organism which resulted from these achievements, prepared the way for the acceptance of the still greater revolution which the Darwinian epoch brought about in the views entertained by naturalists of the relations of plants and animals to each other and to their surroundings.

It has been said that every science of observation begins by going out botanising, by which, I suppose, is meant that collecting and recording observations is the first thing to be done in entering on a new field of inquiry. The remark would scarcely be true of physiology, even at the earliest stage of its development, for the most elementary of its facts could scarcely be picked up as one gathers flowers in a wood. Each of the processes which go to make up the complex of life requires separate investigation, and in each case the investigation must consist in first splitting up the process into its constituent phenomena, and then determining their relation to each other, to the process of which they form part, and to the conditions under which they manifest themselves. It will, I think, be found that even in the simplest inquiry into the nature of vital processes some such order as this is followed. Thus, for example, if muscular contraction be the subject on which we seek information, it is obvious that, in order to measure its duration, the mechanical work it accomplishes, the heat wasted in doing it, the electro-motive forces which it develops, and the changes of form associated with these phenomena, special modes of observation must be used for each of them, that each measurement must be in the first instance separately made, under special conditions, and by methods specially adapted to the required purpose. In the synthetic part of the inquiry the guidance of experiment must again be sought for the purpose of discriminating between apparent and real causes, and of determining the order in which the phenomena occur. Even the simplest experimental investigations of vital processes are beset with difficulties. For, in addition to the extreme complexity of the phenomena to be examined and the uncertainties which arise from the relative inconstancy of the conditions of all that goes on in the living organism, there is this additional drawback, that, whereas in the exact sciences experiment is guided by well-ascertained laws, here the only principle of universal application is that of adaptation, and that even this cannot, like a law of physics, be taken as a basis for deductions, but only as a summary expression of that relation between external exciting causes and the reactions to which they give rise, which, in accordance with Treviranus' definition, is the essential character of vital activity.

The Specific Energies of the Organism.

When in 1826 J. Müller was engaged in investigating the physiology of vision and hearing he introduced into the discussion a term, 'specific energy,' the use of which by Helmholtz [1] in his physiological writings has rendered it familiar to all students. Both writers mean by the word energy, not the 'capacity of doing work,' but simply *activity*, using it in its old-fashioned meaning, that of the Greek word from which it is derived. With the qualification 'specific' it serves, perhaps, better than any other expression to indicate the way in which adaptation manifests itself. In this more extended sense the 'specific energy' of a part or organ—whether that part be a secreting cell, a motor cell of the brain or spinal cord, or one of the photogenous cells which produce the light of the glowworm, or the protoplasmic plate which generates the discharge of the torpedo—is simply the special action which it *normally* performs, its norma or rule of action being in each instance the *interest of the organism* as a whole of which it forms part, and the exciting cause some influence outside of the excited structure, technically called a stimulus. It thus stands for a characteristic of living structures which seems to be universal. The apparent exceptions are to be found in those bodily activities which, following Bichat, we call vegetative, because they go on, so to speak, as a matter of course; but the more closely we look into them the more does it appear that they form no exception to the general rule, that every link in the chain of living action, however uniform that action may be, is a response to an antecedent influence. Nor can it well be doubted that, as every living cell or tissue is called upon to act in the interest of the whole, the organism must be capable of influencing every part so as to regulate its action. For, although there are some instances in which the channels of this influence are as yet unknown, the tendency of recent investigations has been to diminish the number of such instances. In general there is no difficulty in determining both the nature of the central influence exercised and the relation between it and the normal function. It may help to illustrate this relation to refer to the expressive word *Auslösung* by which it has for many years been designated by German writers. This word stands for the performance of function by the 'letting off' of 'specific energies.' Carrying out the notion of 'letting off' as expressing the link between action and reaction, we might compare the whole process to the mode of working of a repeating clock (or other similar mechanism), in which case the pressure of the finger on the button would represent the external influence or stimulus, the striking of the clock, the normal reaction. And now may I ask you to consider in detail one or two illustrations of physiological reaction—of the *letting off of specific energy?*

[1] *Handb. der physiologischen Optik*, 1886, p. 233. Helmholtz uses the word in the plural—the 'energies of the nerves of special sense.'

The repeater may serve as a good example, inasmuch as it is, in biological language, a highly differentiated structure, to which a single function is assigned. So also in the living organism, we find the best examples of specific energy where Müller found them, namely, in the most differentiated, or, as we are apt to call them, the *highest* structures. The retina, with the part of the brain which belongs to it, together constitute such a structure, and will afford us therefore the illustration we want, with this advantage for our present purpose, that the phenomena are such as we all have it in our power to observe in ourselves. In the visual apparatus the principle of *normality* of reaction is fully exemplified. In the physical sense the word 'light' stands for ether vibrations, but in the sensuous or subjective sense for sensations. The swings are the stimulus, the sensations are the reaction. Between the two comes the link, the 'letting off,' which it is our business to understand. Here let us remember that the man who first recognised this distinction between the physical and the physiological was not a biologist, but a physicist. It was Young who first made clear (though his doctrine fell on unappreciative ears) that, although in vision the external influences which give rise to the sensation of light are infinitely varied, the responses need not be more than three in number, each being, in Müller's language, a 'specific energy' of some part of the visual apparatus. We speak of the organ of vision as *highly differentiated*, an expression which carries with it the suggestion of a distinction of rank between different vital processes. The suggestion is a true one; for it would be possible to arrange all those parts or organs of which the bodies of the *higher* animals consist in a series, placing at the lower end of the series those of which the functions are continuous, and therefore called vegetative; at the other, those highly specialised structures, as, *e.g.*, those in the brain, which in response to physical light produce physiological, that is subjective, light; or, to take another instance, the so-called motor cells of the surface of the brain, which in response to a stimulus of much greater complexity produce voluntary motion. And just as in civilised society an individual is valued according to his power of doing one thing well, so the high rank which is assigned to the structure, or rather to the 'specific energy' which it represents, belongs to it by virtue of its specialisation. And if it be asked how this conformity is manifested, the answer is, by the quality, intensity, duration, and extension of the response, in all which respects vision serves as so good an example, that we can readily understand how it happened that it was in this field that the relation between response and stimulus was first clearly recognised. I need scarcely say that, however interesting it might be to follow out the lines of inquiry thus indicated, we cannot attempt it this evening. All that I can do is to mention one or two recent observations which, while they serve as illustrations, may perhaps be sufficiently novel to interest even those who are at home in the subject.

Probably everyone is acquainted with some of the familiar proofs that an object is seen for a much longer period than it is actually exposed to view; that the visual reaction lasts much longer than its cause. More precise observations teach us that this response is regulated according to laws which it has in common with all the higher functions of an organism. If, for example, the cells in the brain of the torpedo are 'let off'—that is, awakened by an external stimulus—the electrical discharge, which, as in the case of vision, follows after a certain interval, lasts a certain time, first rapidly increasing to a maximum of intensity, then more slowly diminishing. In like manner, as regards the visual apparatus, we have, in the response to a sudden invasion of the eye by light, a rise and fall of a similar character. In the case of the electrical organ, and in many analogous instances, it is easy to investigate the time relations of the successive phenomena, so as to represent them graphically. Again, it is found that in many physiological reactions, the period of rising 'energy' (as Helmholtz called it) is followed by a period during which the responding structure is not only inactive, but its capacity for energising is so completely lost that the same exciting cause which a moment before 'let off' the characteristic response is now without effect. As regards vision, it has long been believed that these general characteristics of physiological reaction have their counterpart in the visual process, the most striking evidence being that in the contemplation of a lightning flash—or, better, of an instantaneously illuminated white disc [1]—the eye seems to receive a double stroke, indicating that, although the stimulus is single and instantaneous, the response is reduplicated. The most precise of the methods we until lately possessed for investigating the wax and wane of the visual reaction, were not only difficult to carry out but left a large margin of uncertainty. It was therefore particularly satisfactory when M. Charpentier, of Nancy, whose merits as an investigator are perhaps less known than they deserve to be, devised an experiment of extreme simplicity which enables us, not only to observe, but to measure with great facility both phases of the reaction. It is difficult to explain even the simplest apparatus without diagrams; you will, however, understand the experiment if you will imagine that you are contemplating a disc, like those ordinarily used for colour mixing; that it is divided by two radial lines which diverge from each other at an angle of 60°; that the sector which these lines enclose is white, the rest black; that the disc revolves slowly, about once in two seconds. You then see, close to the front edge of the advancing sector, a black bar, followed by a second at the same distance from itself but much fainter. Now the scientific value of the experiment consists in this, that the angular distance of the bar from the black border is in proportion to the frequency of the revolutions—the faster the wider. If, for

[1] The phenomenon is best seen when, in a dark room, the light of a luminous spark is thrown on to a white screen with the aid of a suitable lens.

example, when the disc makes half a revolution in a second the distance is ten degrees, this obviously means that when light bursts into the eye, the extinction happens one-eighteenth of a second after the excitation.[1]

The fact thus demonstrated, that the visual reaction consequent on an instantaneous illumination exhibits the alternations I have described, has enabled M. Charpentier to make out another fact in relation to the visual reaction which is, I think, of equal importance. In all the instances, excepting the retina, in which the physiological response to stimulus has a definite time-limitation, and in so far resembles an explosion—in other words, in all the higher forms of specific energy, it can be shown experimentally that the process is propagated from the part first directly acted on to other contiguous parts of similar endowment. Thus in the simplest of all known phenomena of this kind, the electrical change, by which the leaf of the Dionæa plant responds to the slightest touch of its sensitive hairs, is propagated from one side of the leaf to the other, so that in the opposite lobe the response occurs after a delay which is proportional to the distance between the spot excited and the spot observed. That in the retina there is also such propagation has not only been surmised from analogy, but inferred from certain observed facts. M. Charpentier has now been able by a method which, although simple, I must not attempt to describe, not only to prove its existence, but to measure its rate of progress over the visual field.

There is another aspect of the visual response to the stimulus of light which, if I am not trespassing too long on your patience, may, I think, be interesting to consider. As the relations between the sensations of colour and the physical properties of the light which excites them, are among the most certain and invariable in the whole range of vital reactions, it is obvious that they afford as fruitful a field for physiological investigation as those in which white light is concerned. We have on one side physical facts, that is, wave-lengths or vibration-rates; on the other, facts in consciousness—namely, sensations of colour—so simple that notwithstanding their subjective character there is no difficulty in measuring either their intensity or their duration. Between these there are *lines of influence*, neither physical nor psychological, which pass from the former to the latter through the visual apparatus (retina, nerve, brain). It is these lines of influence which interest the physiologist. The structure of the visual apparatus affords us no clues to trace them by. The most important fact we know about them is that they must be at least three in number.

It has been lately assumed by some that vision, like every other specific energy, having been developed progressively, objects were seen

[1] Charpentier, 'Réaction oscillatoire de la Rétine sous l'influence des excitations lumineuses,' *Archives de Physiol.*, vol. xxiv. p. 541, and *Propagation de l'action oscillatoire*, &c., p. 362.

by the most elementary forms of eye only in chiaroscuro, that afterwards some colours were distinguished, eventually all. As regards hearing it is so. The organ which, on structural grounds, we consider to represent that of hearing in animals low in the scale of organisation—as, *e.g.*, in the Ctenophora—has nothing to do with sound,[1] but confers on its possessor the power of judging of the direction of its own movements in the water in which it swims, and of guiding these movements accordingly. In the lowest vertebrates, as, *e.g.*, in the dogfish, although the auditory apparatus is much more complicated in structure, and plainly corresponds with our own, we still find the particular part which is concerned in hearing scarcely traceable. All that is provided for is that sixth sense, which the higher animals also possess, and which enables them to judge of the direction of their own movements. But a stage higher in the vertebrate series we find the special mechanisms by which we ourselves appreciate sounds beginning to appear—not supplanting or taking the place of the imperfect organ, but added to it. As regards hearing, therefore, a new function is acquired without any transformation or fusion of the old into it. We ourselves possess the sixth sense, by which we keep our balance and which serves as the guide to our bodily movements. It resides in the part of the internal ear which is called the labyrinth. At the same time we enjoy along with it the possession of the cochlea, that more complicated apparatus by which we are able to hear sounds and to discriminate their vibration-rates.

As regards vision, evidence of this kind is wanting. There is, so far as I know, no proof that visual organs which are so imperfect as to be incapable of distinguishing the forms of objects, may not be affected differently by their colours. Even if it could be shown that the least perfect forms of eye possess only the power of discriminating between light and darkness, the question whether in our own such a faculty exists separately from that of distinguishing colours is one which can only be settled by experiment. As in all sensations of colour the sensation of brightness is mixed, it is obvious that one of the first points to be determined is whether the latter represents a 'specific energy' or merely a certain combination of specific energies which are excited by colours. The question is not whether there is such a thing as white light, but whether we possess a separate faculty by which we judge of light and shade—a question which, although we have derived our knowledge of it chiefly from physical experiment, is one of eye and brain, not of wavelengths or vibration-rates, and is therefore essentially physiological.

There is a German proverb which says, 'Bei Nacht sind alle Katzen grau.' The fact which this proverb expresses presents itself experimentally when a spectrum projected on a white surface is watched, while the

[1] Verworn, 'Gleichgewicht u. Otolithenorgan,' *Pflüger's Archiv*, vol. l. p. 423; also Ewald's researches on the Labyrinth as a Sense-organ (*Ueber das Endorgan des Nervus octavus*, Wiesbaden, 1892).

intensity of the light is gradually diminished. As the colours fade away they become indistinguishable as such, the last seen being the primary red and green. Finally they also disappear, but a grey band of light still remains, of which the most luminous part is that which before was green.[1] Without entering into details, let us consider what this tells us of the specific energy of the visual apparatus. Whether or not the faculty by which we see grey in the dark is one which we possess in common with animals of imperfectly developed vision, there seems little doubt that there are individuals of our own species who, in the fullest sense of the expression, have no eye for colour; in whom all colour sense is absent; persons who inhabit a world of grey, seeing all things as they might have done had they and their ancestors always lived nocturnal lives. In the theory of colour vision, as it is commonly stated, no reference is made to such a faculty as we are now discussing.

Professor Hering, whose observations as to the diminished spectrum I referred to just now, who was among the first to subject the vision of the *totally* colour-blind to accurate examination, is of opinion, on that and on other grounds, that the sensation of light and shade is a specific faculty. Very recently the same view has been advocated on a wide basis by a distinguished psychologist, Professor Ebbinghaus.[2] Happily, as regards the actual experimental results relating to both these main subjects, there seems to be a complete coincidence of observation between observers who interpret them differently. Thus the recent elaborate investigations of Captain Abney[3] (with General Festing), representing graphically the results of his measurements of the subjective values of the different parts of the diminished spectrum, as well as those of the fully illuminated spectrum as seen by the totally colour-blind, are in the closest accord with the observations of Hering, and have, moreover, been substantially confirmed in both points by the measurements of Dr. König in Helmholtz' laboratory at Berlin.[4] That observers of such eminence as the three persons whom I have mentioned, employing different methods and with a different purpose in view, and without reference to each other's work, should arrive in so complicated an inquiry at coincident results, augurs well for the speedy settlement of this long-debated question. At present the inference seems to be that such a specific energy as Hering's theory of vision postulates actually exists, and that it has for associates the colour-perceiving activities of the visual apparatus, provided that these are present; but that whenever the intensity

[1] Hering, 'Untersuch. eines total Farbenblinden,' *Pflüger's Arch.*, vol. xlix., 1891, p. 563.

[2] Ebbinghaus, 'Theorie des Farbensehens,' *Zeitschr. f. Psychol.*, vol. v., 1893, p. 145.

[3] Abney and Festing, Colour Photometry, Part III. *Phil. Trans.*, vol. clxxxiiiA, 1891, p. 531.

[4] König, 'Ueber den Helligkeitswerth der Spectralfarben bei verschiedener absoluter Intensität,' *Beiträge zur Psychologie*, &c., 'Festschrift zu H. von Helmholtz,' Siebzigsten Geburtstage,' 1891, p. 309.

of the illumination is below the chromatic threshold—that is, too feeble to awaken these activities—or when, as in the totally colour-blind, they are wanting, it manifests itself independently; all of which can be most easily understood on such a hypothesis as has lately been suggested in an ingenious paper by Mrs. Ladd Franklin,[1] that each of the elements of the visual apparatus is made up of a central structure for the sensation of light and darkness, with collateral appendages for the sensations of colour—it being, of course, understood that this is a mere diagrammatic representation, which serves no purposes beyond that of facilitating the conception of the relation between the several 'specific energies.'

Experimental Psychology.

Resisting the temptation to pursue this subject further, I will now ask you to follow me into a region which, although closely connected with the subjects we have been considering, is beset with greater difficulties—the subject in which, under the name of Physiological or Experimental Psychology, physiologists and psychologists have of late years taken a common interest—a borderland not between fact and fancy, but between two methods of investigation of questions which are closely related, which here, though they do not overlap, at least interdigitate. It is manifest that, quite irrespectively of any foregone conclusion as to the dependence of mind on processes of which the biologist is accustomed to take cognizance, mind must be regarded as one of the 'specific energies' of the organism, and should on that ground be included in the subject-matter of physiology. As, however, our science, like other sciences, is limited not merely by its subject but also by its method, it actually takes in only so much of psychology as is experimental. Thus sensation, although it is psychological, and the investigation of its relation to the special structures by which the mind keeps itself informed of what goes on in the outside world, have always been considered to be in the physiological sphere. And it is by anatomical researches relating to the minute structure and to the development of the brain, by observation of the facts of disease, and, above all, by physiological experiment, that those changes in the ganglion cells of the brain and spinal cord which are the immediate antecedents of every kind of bodily action have been traced. Between the two—that is, between sensation and the beginning of action—there is an intervening region which the physiologist has hitherto willingly resigned to psychology, feeling his incompetence to use the only instrument by which it can be explored—that of introspection. This consideration enables us to understand the course which the new study (I will not claim for it the title of a new science, regarding it as merely a part of the great science of life) has hitherto

[1] Christine Ladd Franklin, 'Eine neue Theorie der Lichtempfindungen,' *Zeitschr. für Psychologie*, vol. iv., 1893, p. 211; see also the Proceedings of the last Psychological Congress in London, 1892.

followed, and why physiologists have been unwilling to enter on it. The study of the less complicated internal relations of the organism has afforded so many difficult problems that the most difficult of all have been deferred; so that although the psycho-physical method was initiated by E. H. Weber in the middle of the present century, by investigations[1] which formed part of the work done at that epoch of discovery, and although Professor Wundt, also a physiologist, has taken a larger share in the more recent development of the new study, it is chiefly by psychologists that the researches which have given to it its importance as a new discipline have been conducted.

Although, therefore, experimental psychology has derived its methods from physical science, the result has been not so much that physiologists have become philosophers, as that philosophers have become experimental psychologists. In our own universities, in those of America, and still more in those of Germany, psychological students of mature age are to be found who are willing to place themselves in the dissecting-room side by side with beginners in anatomy, in order to acquire that exact knowledge of the framework of the organism without which no man can understand its working. Those, therefore, who are apprehensive lest the regions of mind should be invaded by the *insaniens sapientia* of the laboratory, may, I think, console themselves with the thought that the invaders are for the most part men who before they became laboratory workers had already given their allegiance to philosophy; their purpose being not to relinquish definitively, but merely to lay aside for a time, the weapons in the use of which they had been trained, in order to learn the use of ours. The motive that has encouraged them has not been any hope of finding an experimental solution of any of the ultimate problems of philosophy, but the conviction that, inasmuch as the relation between mental stimuli and the mental processes which they awaken is of the same order with the relation between every other vital process and its specific determinant, the only hope of ascertaining its nature must lie in the employment of the same methods of comparative measurement which the biologist uses for similar purposes. Not that there is necessarily anything scientific in mere measurement, but that measurement affords the only means by which it can be determined whether or not the same conformity in the relation between stimulus and reaction which we have accepted as the fundamental characteristic of life, is also to be found in mind, notwithstanding that mental processes have no known physical concomitants. The results of experimental psychology tend to show that it is so, and consequently that in so far the processes in question are as truly functions of organism as the contraction of a muscle, or as the changes produced in the retinal pigment by light.

I will make no attempt even to enumerate the special lines of inquiry

[1] Weber's researches were published in Wagner's *Handwörterbuch*, I think, in 1849.

which during the last decade have been conducted with such vigour in all parts of the world, all of them traceable to the influence of the Leipzig school; but will content myself with saying that the general purpose of these investigations has been to determine with the utmost attainable precision the nature of psychical relations. Some of these investigations begin with those simpler reactions which more or less resemble those of an automatic mechanism, proceeding to those in which the resulting action or movement is modified by the influence of auxiliary or antagonistic conditions, or changed by the simultaneous or antecedent action on the reagent of other stimuli, in all of which cases the effect can be expressed quantitatively; others lead to results which do not so readily admit of measurement. In pursuing this course of inquiry the physiologist finds himself as he proceeds more and more the *coadjutor* of the psychologist, less and less his *director*; for whatever advantage the former may have in the mere *technique* of observation, the things with which he has to do are revealed only to introspection, and can be studied only by methods which lie outside of his sphere. I might in illustration of this refer to many recent experimental researches—such, for example, as those by which it has been sought to obtain exact data as to the physiological concomitants of pleasure and of pain, or as to the influence of weariness and recuperation, as modifiers of psychological reactions. Another outwork of the mental citadel which has been invaded by the experimental method is that of memory. Even here it can be shown that in the comparison of transitory as compared with permanent memory—as, for example, in the getting off by heart of a wholly uninteresting series of words, with subsequent oblivion and reacquisition—the labour of acquiring and reacquiring may be measured, and consequently the relation between them; and that this ratio varies according to a simple numerical law.

I think it not unlikely that the only effect of what I have said may be to suggest to some of my hearers the question, What is the use of such inquiries? Experimental psychology has, to the best of my knowledge, no technical application. The only satisfactory answer I can give is that it has exercised, and will exercise in future, a helpful influence on the science of life. Every science of observation, and each branch of it, derives from the peculiarities of its methods certain tendencies which are apt to predominate unduly. We speak of this as specialisation, and are constantly striving to resist its influence. The most successful way of doing so is by availing ourselves of the counteracting influence which two opposite tendencies mutually exercise when they are simultaneous. He that is skilled in the methods of introspection naturally (if I may be permitted to say so) looks at the same thing from an opposite point of view to that of the experimentalist. It is, therefore, good that the two should so work together that the tendency of the experimentalist to imagine the existence of mechanism where none

is proved to exist—of the psychologist to approach the phenomena of mind too exclusively from the subjective side—may mutually correct and assist each other.

Phototaxis and Chemiotaxis.

Considering that every organism must have sprung from a unicellular ancestor, some have thought that unless we are prepared to admit a deferred epigenesis of mind, we must look for psychical manifestations even among the lowest animals, and that as in the protozoon all the vital activities are blended together, mind should be present among them not merely potentially but actually, though in diminished degree.

Such a hypothesis involves ultimate questions which it is unnecessary to enter upon: it will, however, be of interest in connection with our present subject to discuss the phenomena which served as a basis for it—those which relate to what may be termed the behaviour of unicellular organisms and of individual cells, in so far as these last are capable of reacting to external influences. The observations which afford us most information are those in which the stimuli employed can be easily measured, such as electrical currents, light, or chemical agents in solution.

A single instance, or at most two, must suffice to illustrate the influence of light in directing the movements of freely moving cells, or, as it is termed, phototaxis. The rod-like purple organism called by Engelmann *Bacterium photometricum* [1] is such a light-lover that if you place a drop of water containing these organisms under the microscope, and focus the smallest possible beam of light on a particular spot in the field, the spot acts as a light trap and becomes so crowded with the little rodlets as to acquire a deep port-wine colour. If instead of making his trap of white light, he projected on the field a microscopic spectrum, Engelmann found that the rodlets showed their preference for a spectral colour which is absorbed when transmitted through their bodies. By the aid of a light trap of the same kind, the very well-known spindle-shaped and flagellate cell of Euglena can be shown to have a similar power of discriminating colour, but its preference is different. This familiar organism advances with its flagellum forwards, the sharp end of the spindle having a red or orange eye point. Accordingly, the light it loves is again that which is most absorbed—viz., the blue of the spectrum (line F).

These examples may serve as an introduction to a similar one in which the directing cause of movement is not physical but chemical. The spectral light trap is used in the way already described; the or-

[1] Engelmann, 'Bacterium photometricum,' *Onderzoek. Physiol. Lab. Utrecht*, vol. vii. p. 200; also 'Ueber Licht- u. Farbenperception niederster Organismen,' *Pflüger's Arch.*, vol. xxix. p. 387.

ganisms to be observed are not coloured, but bacteria of that common sort which twenty years ago we used to call *Bacterium termo*, and which is recognised as the ordinary determining cause of putrefaction. These organisms do not care for light, but are great oxygen-lovers. Consequently, if you illuminate with your spectrum a filament of a confervoid alga, placed in water containing bacteria, the assimilation of carbon and consequent disengagement of oxygen are most active in the part of the filament which receives the red rays (B to C). To this part, therefore, where there is a dark band of absorption, the bacteria which want oxygen are attracted in crowds. The motive which brings them together is their desire for oxygen. Let us compare other instances in which the source of attraction is food.

The plasmodia of the myxomycetes, particularly one which has been recently investigated by Mr. Arthur Lister,[1] may be taken as a typical instance of what may be called the chemical allurement of living protoplasm. In this organism, which in the active state is an expansion of labile living material, the delicacy of the reaction is comparable to that of the sense of smell in those animals in which the olfactory organs are adapted to an aquatic life. Just as, for example, the dogfish is attracted by food which it cannot see, so the plasmodium of Badhamia becomes aware, as if it smelled it, of the presence of its food—a particular kind of fungus. I have no diagram to explain this, but will ask you to imagine an expansion of living material, quite structureless, spreading itself along a wet surface; that this expansion of transparent material is bounded by an irregular coast-line; and that somewhere near the coast there has been placed a fragment of the material on which the Badhamia feeds. The presence of this bit of *Stereum* produces an excitement at the part of the plasmodium next to it. Towards this centre of activity streams of living material converge. Soon the afflux leads to an outgrowth of the plasmodium, which in a few minutes advances towards the desired fragment, envelopes, and incorporates it.

May I give you another example also derived from the physiology of plants? Very shortly after the publication of Engelmann's observations of the attraction of bacteria by oxygen, Pfeffer made the remarkable discovery that the movements of the antherozoids of ferns and of mosses are guided by impressions derived from chemical sources, by the allurement exercised upon them by certain chemical substances in solution—in one of the instances mentioned by sugar, in the other by an organic acid. The method consisted in introducing the substance to be tested, in any required strength, into a minute capillary tube closed at one end, and placing it under the microscope in water inhabited by antherozoids, which thereupon showed their predilection for the substance, or the contrary, by its effect on their movements. In accordance with the

[1] Lister, 'On the Plasmodium of *Badhamia utricularis*, &c.,' *Annals of Botany*, No. 5, June 1888.

principle followed in experimental psychology, Pfeffer [1] made it his object to determine, not the relative effects of different doses, but the smallest perceptible increase of dose which the organism was able to detect, with this result—that, just as in measurements of the relation between stimulus and reaction in ourselves we find that the sensational value of a stimulus depends, not on its absolute intensity, but on the ratio between that intensity and the previous excitation, so in this simplest of vital reagents the same so-called psycho-physical law manifests itself. It is not, however, with a view to this interesting relation that I have referred to Pfeffer's discovery, but because it serves as a centre around which other phenomena, observed alike in plants and animals, have been grouped. As a general designation of reactions of this kind Pfeffer devised the term Chemotaxis, or, as we in England prefer to call it, Chemiotaxis. Pfeffer's contrivance for chemiotactic testing was borrowed from the pathologists, who have long used it for the purpose of determining the relation between a great variety of chemical compounds or products, and the colourless corpuscles of the blood. I need, I am sure, make no apology for referring to a question which, although purely pathological, is of very great biological interest—the theory of the process by which, not only in man, but also, as Metschnikoff has strikingly shown, in animals far down in the scale of development, the organism protects itself against such harmful things as, whether particulate or not, are able to penetrate its framework. Since Cohnheim's great discovery in 1867 we have known that the central phenomenon of what is termed by pathologists *inflammation* is what would now be called a chemiotactic one; for it consists in the gathering together, like that of vultures to a carcase, of those migratory cells which have their home in the blood stream and in the lymphatic system, to any point where the living tissue of the body has been injured or damaged, as if the products of disintegration which are set free where such damage occurs were attractive to them.

The fact of chemiotaxis, therefore, as a constituent phenomenon of the process of inflammation, was familiar in pathology long before it was understood. Cohnheim himself attributed it to changes in the channels along which the cells moved, and this explanation was generally accepted, though some writers, at all events, recognised its incompleteness. But no sooner was Pfeffer's discovery known than Leber,[2] who for years had been working at the subject from the pathological side, at once saw that the two processes were of similar nature. Then followed a variety of researches of great interest, by which the importance of chemiotaxis in relation to the destruction of disease-producing microphytes was proved,

[1] Pfeffer, *Untersuch a. d. botan. Institute z. Tübingen*, vol. i., part 3, 1884.

[2] Leber, 'Die Anhäufung der Leucocyten am Orte des Entzündungsreizes,' &c. *Die Entstehung der Enztündung*, &c., pp. 423–464, Leipzig, 1891.

that of Buchner[1] on the chemical excitability of leucocytes being among the most important. Much discussion has taken place, as many present are aware, as to the kind of wandering cells, or leucocytes, which in the first instance attack morbific microbes, and how they deal with them. The question is not by any means decided. It has, however, I venture to think, been conclusively shown that the process of destruction is a chemical one, that the destructive agent has its source in the chemiotactic cells—that is, cells which act under the orders of chemical stimuli. Two Cambridge observers, Messrs. Kanthack and Hardy,[2] have lately shown that, in the particular instance which they have investigated, the cells which are most directly concerned in the destruction of morbific *bacilli*, although chemiotactic, do not possess the power of incorporating either bacilli or particles of any other kind. While, therefore, we must regard the relation between the process of devitalising and that of incorporating as not yet sufficiently determined, it is now no longer possible to regard the latter as essential to the former.

There seems, therefore, to be very little doubt that chemiotactic cells are among the agents by which the human or animal organism protects itself against infection. There are, however, many questions connected with this action which have not yet been answered. The first of these are chemical ones—that of the nature of the attractive substance and that of the process by which the living carriers of infection are destroyed. Another point to be determined is how far the process admits of adaptation to the particular infection which is present in each case, and to the state of liability or immunity of the infected individual. The subject is therefore of great complication. None of the points I have suggested can be settled by experiments in glass tubes such as I have described to you. These serve only as indications of the course to be followed in much more complicated and difficult investigations—when we have to do with acute diseases as they actually affect ourselves or animals of similar liabilities to ourselves, and find ourselves face to face with the question of their causes.

It is possible that many members of the Association are not aware of the unfavourable—I will not say discreditable—position that this country at present occupies in relation to the scientific study of this great subject—the causes and mode of prevention of infectious diseases. As regards administrative efficiency in matters relating to public health England was at one time far ahead of all other countries, and still retains its superiority; but as regards scientific knowledge we are, in this subject as in others, content to borrow from our neighbours. Those who desire either to learn the methods of research or to carry out scientific

[1] Buchner, 'Die chem. Reizbarkeit der Leucocyten,' &c., *Berliner klin. Woch.*, 1890, No. 17.

[2] Kanthack and Hardy, 'On the Characters and Behaviour of the Wandering Cells of the Frog,' *Proceedings of the Royal Society*, vol. lii. p. 267.

inquiries have to go to Berlin, to Munich, to Breslau, or to the Pasteur Institute in Paris to obtain what England ought long ago to have provided. For to us, from the spread of our race all over the world, the prevention of acute infectious diseases is more important than to any other nation. At the beginning of this address I urged the claims of pure science. If I could, I should feel inclined to speak even more strongly of the application of science to the discovery of the causes of acute diseases. May I express the hope that the effort which is now being made to establish in England an Institution for this purpose not inferior in efficiency to those of other countries, may have the sympathy of all present? And now may I ask your attention for a few moments more to the subject that more immediately concerns us?

Conclusion.

The purpose which I have had in view has been to show that there is one principle—that of adaptation—which separates biology from the exact sciences, and that in the vast field of biological inquiry the end we have is not merely, as in natural philosophy, to investigate the relation between a phenomenon and the antecedent and concomitant conditions on which it depends, but to possess this knowledge in constant reference to the interest of the organism. It may perhaps be thought that this way of putting it is too teleological, and that in taking, as it were, as my text this evening so old-fashioned a biologist as Treviranus, I am yielding to a retrogressive tendency. It is not so. What I have desired to insist on is that *organism* is a fact which encounters the biologist at every step in his investigations; that in referring it to any general biological principle, such as adaptation, we are only referring it to itself, not explaining it; that no explanation will be attainable until the conditions of its coming into existence can be subjected to experimental investigation so as to correlate them with those of processes in the non-living world.

Those who were present at the meeting of the British Association at Liverpool will remember that then, as well as at some subsequent meetings, the question whether the conditions necessary for such an inquiry could be realised was a burning one. This is no longer the case. The patient endeavours which were made about that time to obtain experimental proof of what was called *abiogenesis*, although they conduced materially to that better knowledge which we now possess of the conditions of life of bacteria, failed in the accomplishment of their purpose. The question still remains undetermined; it has, so to speak, been adjourned *sine die*. The only approach to it lies at present in the investigation of those rare instances in which, although the relations between a living organism and its environment ceases as a watch stops when it

has not been wound, these relations can be re-established—the process of life re-awakened—by the application of the required stimulus.

I was also desirous to illustrate the relation between physiology and its two neighbours on either side, natural philosophy (including chemistry) and psychology. As regards the latter I need add nothing to what has already been said. As regards the former, it may be well to notice that although physiology can never become a mere branch of applied physics or chemistry, there are parts of physiology wherein the principles of these sciences may be applied directly. Thus, in the beginning of the century, Young applied his investigations as to the movements of liquids in a system of elastic tubes, directly to the phenomena of the circulation; and a century before, Borelli successfully examined the mechanisms of locomotion and the action of muscles, without reference to any, excepting mechanical principles. Similarly, the foundation of our present knowledge of the process of nutrition was laid in the researches of Bidder and Schmidt, in 1851, by determinations of the weight and composition of the body, the daily gain of weight by food or oxygen, the daily loss by the respiratory and other discharges, all of which could be accomplished by chemical means. But in by far the greater number of physiological investigations, both methods (the physical or chemical and the physiological) must be brought to bear on the same question—to co-operate for the elucidation of the same problem. In the researches, for example, which during several years have occupied Professor Bohr, of Copenhagen, relating to the exchange of gases in respiration, he has shown that factors purely physical—namely, the partial pressures of oxygen and carbon dioxide in the blood which flows through the pulmonary capillaries—are, so to speak, interfered with in their action by the 'specific energy' of the pulmonary tissue, in such a way as to render this fundamental process, which, since Lavoisier, has justly been regarded as one of the most important in physiology, much more complicated than we for a long time supposed it to be. In like manner Heidenhain has proved that the process of lymphatic absorption, which before we regarded as dependent on purely mechanical causes—*i.e.*, differences of pressure—is in great measure due to the specific energy of cells, and that in various processes of secretion the principal part is not, as we were inclined not many years ago to believe, attributable to liquid diffusion, but to the same agency. I wish that there had been time to have told you something of the discoveries which have been made in this particular field by Mr. Langley, who has made the subject of 'specific energy' of secreting-cells his own. It is in investigations of this kind, of which any number of examples could be given, in which vital reactions mix themselves up with physical and chemical ones so intimately that it is difficult to draw the line between them, that the physiologist derives most aid from whatever chemical and physical training he may be fortunate enough to possess.

There is, therefore, no doubt as to the advantages which physiology derives from the exact sciences. It could scarcely be averred that they would benefit in anything like the same degree from closer association with the science of life. Nevertheless, there are some points in respect of which that science may have usefully contributed to the advancement of physics or of chemistry. The discovery of Graham as to the characters of colloid substances, and as to the diffusion of bodies in solution through membranes, would never have been made had not Graham 'ploughed,' so to speak, 'with our heifer.' The relations of certain colouring matters to oxygen and carbon dioxide would have been unknown, had no experiments been made on the respiration of animals and the assimilative process in plants; and, similarly, the vast amount of knowledge which relates to the chemical action of ferments must be claimed as of physiological origin. So also there are methods, both physical and chemical, which were originally devised for physiological purposes. Thus the method by which meteorological phenomena are continuously recorded graphically, originated from that used by Ludwig (1847) in his 'Researches on the Circulation'; the mercurial pump, invented by Lothar Meyer, was perfected in the physiological laboratories of Bonn and Leipzig; the rendering the galvanometer needle aperiodic by damping was first realised by du Bois-Reymond—in all of which cases invention was prompted by the requirements of physiological research.

Let me conclude with one more instance of a different kind, which may serve to show how, perhaps, the wonderful ingenuity of contrivance which is displayed in certain organised structures—the eye, the ear, or the organ of voice—may be of no less interest to the physicist than to the physiologist. Johannes Müller, as is well known, explained the compound eye of insects on the theory that an erect picture is formed on the convex retina by the combination of pencils of light, received from different parts of the visual field through the eyelets (ommatidia) directed to them. Years afterwards it was shown that in each eyelet an image is formed which is reversed. Consequently, the mosaic theory of Müller was for a long period discredited on the ground that an erect picture could not be made up of 'upside-down' images. Lately the subject has been reinvestigated, with the result that the mosaic theory has regained its authority. Professor Exner [1] has proved photographically that behind each part of the insect's eye an erect picture is formed of the objects towards which it is directed. There is, therefore, no longer any difficulty in understanding how the whole field of vision is mapped out as consistently as it is imaged on our own retina, with the difference, of course, that the picture is erect. But behind this fact lies a physical question—that of the relation between the erect picture which is photographed and the optical structure of the crystal cones which produce it—

[1] Exner, *Die Physiologie der facettirten Augen von Krebsen u. Insecten*, Leipzig, 1891.

a question which, although we cannot now enter upon it, is quite as interesting as the physiological one.

With this history of a theory which, after having been for thirty years disbelieved, has been reinstated by the fortunate combination of methods derived from the two sciences, I will conclude. It may serve to show how, though physiology can never become a part of natural philosophy, the questions we have to deal with are cognate. Without forgetting that every phenomenon has to be regarded with reference to its useful purpose in the organism, the aim of the physiologist is not to inquire into final causes, but to investigate processes. His question is ever How, rather than Why.

May I illustrate this by a simple, perhaps too trivial, story, which derives its interest from its having been told of the childhood of one of the greatest natural philosophers of the present century? [1] He was even then possessed by that insatiable curiosity which is the first quality of the investigator; and it is related of him that his habitual question was 'What is the *go* of it?' and if the answer was unsatisfactory, 'What is the particular go of it?' That North Country boy became Professor Clerk Maxwell. The questions he asked are those which in our various ways we are all trying to answer.

[1] *Life of Clerk Maxwell* (Campbell and Garnett), 1882, p. 28.

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ON THE

STATE OF SCIENCE.

Corresponding Societies.—Report of the Committee, consisting of Professor R. MELDOLA (*Chairman*), MR. T. V. HOLMES (*Secretary*), Mr. FRANCIS GALTON, Sir DOUGLAS GALTON, Sir RAWSON RAWSON, Mr. G. J. SYMONS, Dr. J. G. GARSON, Sir JOHN EVANS, Mr. J. HOPKINSON, Professor T. G. BONNEY, Mr. W. WHITAKER, Mr. W. TOPLEY, Professor E. B. POULTON, Mr. CUTHBERT PEEK, *and* Rev. Canon H. B. TRISTRAM.

THE Corresponding Societies Committee of the British Association beg leave to submit to the General Committee the following report of the proceedings of the Conference held at Edinburgh.

The Council nominated Professor Raphael Meldola, F.R.S., Chairman, Mr. G. J. Symons, F.R.S., Vice-Chairman, and Mr. T. V. Holmes, F.G.S., Secretary to the Conference. These nominations were confirmed by the General Committee at the meeting held at Edinburgh on Wednesday, August 3. The meetings of the Conference were held on Thursday, August 4, and on Tuesday, August 9, at 3.30, in the Justiciary Court. The following Corresponding Societies, out of the sixty on the list, nominated delegates to represent them at the Edinburgh meeting:—

Bath Natural History and Antiquarian Field Club.	Rev. H. H. Winwood, M.A., F.G.S.
Belfast Natural History and Philosophical Society.	Mr. Alexander Tate.
Belfast Naturalists' Field Club . .	Mr. Wm. Gray, M.R.I.A.
Birmingham Natural History and Microscopical Society.	Mr. Charles Pumphrey.
Birmingham Philosophical Society . .	Mr. J. Kenward, F.S.A.
Bristol Naturalists' Society . . .	Prof. Sydney Young, D.Sc.
Burton-on-Trent Natural History and Archæological Society.	Mr. A. L. Stern, B.Sc.
Cardiff Naturalists' Society . . .	Mr. T. H. Thomas.
Chester Society of Natural Science .	Mr. A. O. Walker, F.L.S.
Chesterfield and Midland Counties Institution of Engineers.	Mr. M. H. Mills, F.G.S.

Croydon Microscopical and Natural History Club.	Mr. Thos. Cushing, F.R.A.S.
Cumberland and Westmorland Association for the Advancement of Literature and Science.	Mr. J. G. Goodchild, F.G.S.
Dorset Natural History and Antiquarian Field Club.	Mr. Morton G. Stuart, M.A.
East Kent Natural History Society . .	Mr. A. S. Reid, M.A., F.G.S.
East of Scotland Union of Naturalists' Societies.	Mr. Robert Brown, R.N.
Essex Field Club	Mr. T. V. Holmes, F.G.S.
Federated Institution of Mining Engineers.	Mr. M. H. Mills, F.G.S.
Glasgow, The Geological Society of. .	Mr. James Barclay Murdoch.
Hants Field Club	Rev. A. G. Joyce.
Hertfordshire Natural History Society and Field Club.	Dr. John Morison, F.G.S.
Inverness Scientific Society and Field Club.	Mr. John Horne, F.R.S.E.
Isle of Man Natural History and Antiquarian Society.	Mr. P. M. C. Kermode.
Leeds Geological Association . . .	Mr. B. Holgate, F.G.S.
Liverpool Engineering Society . .	Mr. G. F. Deacon, M.Inst.C.E.
Liverpool Geographical Society . .	Mr. Jas. Irvine, F.R.G.S.
Liverpool Geological Society . . .	Mr. G. H. Morton, F.G.S.
Malton Field Naturalists' and Scientific Society.	Mr. M. B. Slater, F.L.S.
Manchester Geographical Society . .	Mr. Eli Sowerbutts, F.R.G.S.
Manchester Geological Society . .	Mr. Mark Stirrup, F.G.S.
Midland Union of Natural History Societies.	Dr. T. Stacey Wilson, B.Sc.
North of England Institute of Mining Engineers.	Prof. J. H. Merivale, M.A.
North Staffordshire Naturalists' Field Club and Archæological Society.	Dr. J. T. Arlidge, M.A.
Northamptonshire Natural History Society.	Mr. Beeby Thompson, F.G.S.
Paisley Philosophical Institution . .	Mr. James Clark.
Perthshire Society of Natural Science .	Mr. Henry Coates, F.R.S.E.
Rochdale Literary and Scientific Society	Mr. W. Watts, F.G.S.
Somersetshire Archæological and Natural History Society.	Mr. E. Chisholm Batten, M.A., F.R.S.E.
Tyneside Geographical Society . .	Mr. G. E. T. Smithson.
Warwickshire Naturalists' and Archæologists' Field Club.	Mr. W. Andrews, F.G.S.
Woolhope Naturalists' Field Club . .	Rev. J. O. Bevan, M.A.
Yorkshire Geological and Polytechnic Society.	Mr. James W. Davis, F.G.S.
Yorkshire Naturalists' Union . . .	Rev. E. P. Knubley, M.A.

FIRST CONFERENCE, AUGUST 4, 1892.

The Corresponding Societies Committee were represented by Professor R. Meldola (Chairman), Sir Douglas Galton, Mr. G. J. Symons, Mr. W. Whitaker, Mr. E. B. Poulton, Mr. Cuthbert Peek, Dr. Garson, and Mr. T. V. Holmes (Secretary).

The Chairman, after welcoming the delegates to the seventh Conference which had been held under the new rules of the Association, said during the seven years of their existence they had, he ventured to think, done some good work for the Association and for themselves. They

occupied now in relation to the Association very much the same position as one of its Sectional Committees, and for that they were very largely indebted to Sir Douglas Galton, who had very keenly watched their proceedings, and had taken a great interest in them. The report of the Committee was then submitted, and the different subjects which had engaged attention during the year were dealt with under the heading of the Association Sections to which they belong.

Section A.

The Chairman introduced the subject of temperature variations in lakes, rivers, and estuaries.

Meteorological Photography.—Mr. Clayden and Mr. Symons spoke of the desirability of obtaining photographs illustrating damage by whirlwinds and floods, and Mr. W. Watts (Rochdale) said that the society he represented was taking up the subject. Mr. Symons mentioned the Helm Wind of Crossfell, and the peculiar cloud accompanying it; photographs of the latter would be useful. Mr. Watts stated that a difficulty in photographing the effects of floods arose from the state of the weather during their occurrence, and Mr. Cushing (Croydon) exhibited photographs of a recent thunderstorm. The Chairman then remarked that Mr. Kenward (Birmingham), who was unable to be present, had sent a letter stating that for some years in Birmingham meteorological observations had been made in the building called 'The Monument.'

Section B.

The Chairman mentioned the subject of the conditions of the atmosphere in manufacturing towns, and Mr. Mark Stirrup (Manchester) and Mr. Watts (Rochdale) said that observations and experiments were being made thereon in their respective districts.

Section C.

Mr. De Rance (Section C) stated that the Eighteenth Report of the Committee on Underground Waters had been read that morning; that the Committee thought it should be reappointed, and that a volume containing abstracts of the previous reports should be published. The Committee on Coast Erosion hoped to conclude its labours next year. The Committee on Erratic Blocks continued to do good work. The local societies could do much to assist this committee by noting the position of boulders, and by preserving them from destruction.

Mr. Watts (Rochdale) spoke upon the denudation of high-lying drainage areas, and some observations he had made on the amount of material brought down by flood waters, and the degree of protection given by heather, grass, and peat. He was anxious that other districts should take up this inquiry in order that comparisons might be possible. In his district he had found that flood water, after a very heavy flood, had yielded 900 grains of fine material to the gallon, the material mainly consisting of leaves, fibres, seed spores, and little bits of peat.

Dr. H. R. Mill said that something had recently been done in Germany to ascertain the amount of sediment in river water. He thought it very

desirable that a series of observations should be made to determine the relative values of woodlands and heather in protecting land, and was inclined to suggest the formation of a committee for that purpose. Mr. Watts said he would be glad to give information as to the method followed in Rochdale.

Geological Photography.—Mr. Jeffs, Secretary to the Photographic Committee, being absent, had asked Mr. Arthur S. Reid (East Kent) to speak about its work. Mr. Reid said that the number of the photographs was about 700. He exhibited a specimen volume of photographs, and explained the way in which they were mounted and bound. He thought it important that some uniform plan of photographing geological subjects should be adopted, and that the plates used should be orthochromatic or isochromatic. The Committee had asked to be reappointed. He hoped the delegates would try to make their societies active in this matter.

Mr. William Gray said that he thought the Belfast Naturalists' Field Club had its work fairly well represented by the photographs exhibited. They had sent more at first because they then had them in stock; and their quality had improved. They were also photographing antiquities, and producing lantern-slides which were very valuable for educational purposes. His society had an excellent collection of geological and antiquarian lantern-slides which it would be delighted to place at the service of any of the other societies, or of any member of the British Association interested in educational work.

Dr. T. Stacey Wilson mentioned that the Birmingham Philosophical Society had appointed a sub-committee for geological photography.

Mr. J. Barclay Murdoch, as Secretary to the Glasgow Geological Society, said that his society had not sent in any photographs because it had been found difficult to organise the work. He had, however, drawn up a preliminary list of localities to be illustrated, and this list had been circulated among the members, who were asked to return either photographs of the places named or information as to photographs of them already existing.

The Chairman recommended orthochromatic plates. They might be more expensive, but they were decidedly preferable for geological photographs.

SECTION D.

The Chairman invited remarks on the destruction of native plants and of wild birds' eggs.

Disappearance of Native Plants.—The Rev. E. P. Knubley (Yorks. Nat. Union) alluded to the report presented to Section D on this subject, which had been drawn up by Mr. D. E. Boyd. In it were mentioned some of the causes leading to the disappearance of native plants, such as marine erosion, agricultural drainage, and the growth of towns and villages. In addition to these influences were the formation of herbaria, the exchange of botanical specimens, the removal of plants into gardens, and the large numbers of ferns and other plants exposed for sale; and there were great difficulties in the way of any attempts at prohibitive legislation. Many plants had wholly or almost wholly disappeared from the west of Scotland. Mr. Watts said that two or three members of the Rochdale Society proposed to work at this subject. Mr. Mark Stirrup had a short paper by Mr. Leo H. Grindon on the dis-

appearance of wild plants in the neighbourhood of Manchester. The Chairman thought it might be read at the second Conference. Mr. Cuthbert Peek remarked on the great difficulty of obtaining a conviction in cases in which ferns and other wild plants had been taken from private grounds.

Destruction of Wild Birds' Eggs.—The Rev. E. P. Knubley said terrible damage had been done by the destruction of birds' eggs. It was a serious matter, but it was very difficult to know what to do in regard to it. For instance, take the case of the great skua, which nested in the Shetland Islands: in 1890 it is said that not a single chick was reared on the whole of the Foula colony. Every egg was taken, and in 1891 all the eggs of the first laying were taken by the inhabitants and sold to dealers. Other rare birds which nested in the Shetland Islands were also persecuted. He had it on good authority that last year not more than two or three nests of the red-throated diver got off their young; and the black-throated divers were not more fortunate. One shilling apiece was given by dealers for the eggs of the red-throated diver, and 10*s.* a brace for those of the black-throated diver. The whimbrels, which also nested on the same islands, had been reduced to about twenty pairs, and were likely to disappear. The red-necked phalarope was very much in the same circumstances. The dealers gave a commission to a local man, who was to get about 3*d.* a dozen for every egg collected of all sorts and kinds. The local men in turn got the herd boys to sweep the country of every egg they could lay hands on, big and little, and for these they got about 1*d.* a dozen. That was one way in which parts of Scotland had been regularly swept, and that in spite of such protection as the owners could afford. They had men who followed about strangers all day, but the natives took the eggs at night. Then, again, he might mention that he heard that in Edinburgh there was a gentleman who made it his boast that he had over 100 eggs of the golden eagle. What was to be done with a case of that kind? In some parts of England things were not any better. The nesting stations of the lesser tern which existed on the Fifeshire coast, the Lincolnshire coast, and at Spurn, in Yorkshire, would shortly disappear altogether. The oyster-catcher and the Arctic tern had practically ceased to nest on the Lincolnshire and Yorkshire coasts, and the ringed plover was much scarcer than formerly. The redshanks and greenshanks had in many parts also been persecuted to the death. The nests of the bearded reedling, whose breeding station in the British Islands was the Norfolk Broads, had been to his own knowledge systematically poached for sale for a number of years. The only hope seemed to him to be in the creation of a public feeling against the extermination of these birds. It would be difficult to advocate anything like legislation. The most practical plan he had seen was this—that the Imperial Legislature should grant powers to the County Councils to protect known nesting-places in their districts for certain months of the year, say from April 1 to June 30. Such a plan would be simple, and might be effective; but for one thing they should endeavour to do all in their power to help the owners and occupiers of land to protect the birds and their eggs during the breeding season. They might also see if they could not enlist the aid of the gamekeepers, who, with the farmers and proprietors, were beginning to find out that all birds were not their enemies. Collectors and dealers should also be discouraged. Just as he came there that day he had been told that 200 eggs of the stormy petrel

had been taken from one island on the west coast of Ireland and given to one dealer.

Mr. E. B. Poulton (Oxford) said that if they discouraged the purchase of eggs, the trade of the dealer would soon cease.

Mr. G. J. Symons said it was an old saying that there would be no thieves if there were no receivers; and possibly there would be no dealers if there were no collectors. They should discourage as much as they could this spoliation of the nests of rare birds.

Mr. Mills (Chesterfield) thought it would do good if some small recognition were given to gamekeepers to assist in protecting the nests of the birds.

The Chairman asked if it would not strengthen the hands of Mr. Knubley if the meeting was to pass some resolution on the subject.

Sir Douglas Galton hoped any resolution of the kind would make an appeal to egg-collectors.

Section E.

The Chairman remarked that last year there had been a discussion on the cost and age of ordnance maps; also on the teaching of geography in primary schools.

Sir Douglas Galton said that a departmental committee on the subject of ordnance maps had been appointed, and he had been informed by Sir Archibald Geikie that its report would soon be published, and that it would be the means of removing many of the difficulties complained of. It was, of course, no use discussing the matter before the publication of the report.

Mr. Eli Sowerbutts did not expect much from this departmental report, and had little information to offer about the teaching of geography in schools, as he had not had a reply from a single society. But there had been an examination about India in the upper schools of Yorkshire, Cheshire, and Lancashire. Three hundred pupils only asked for papers, and out of 103 who sat three passed. A Cheshire girl of fourteen was first, a Yorkshire man of thirty-one second, and a Yorkshire lad third. This examination amply demonstrated the extreme badness of the teaching of geography in these schools. He would be glad if the delegates would try and help them next year. The examination would be in Yorkshire, and they would go back to the primary schools.

Section G.

Flameless Explosives.—Professor Merivale said he had nothing to report. The Durham strike had interfered with their arrangements, the proposed laboratories having been utilised as stables.

Section H.

Dr. Garson reported that there had been no applications to the Committee last year for aid in connection with anthropological exploration. He contended, however, that local bodies, when they meant to make such explorations, should give them notice. Valuable hints could be given them as to how they should proceed. Local committees intending to explore ancient dwellings, burial places, &c., should communicate with

the Committee in aid of Anthropological Exploration, 3 Hanover Square, London. General Pitt-Rivers was the chairman of this committee, and no one could be better qualified to give advice as to the conduct of an exploration. Local societies might also do useful work by the description of specimens in local museums, accounts of which might be published in their 'Proceedings' for the information of workers dwelling elsewhere.

The Secretary, at the request of the Chairman, read an extract from a letter of Mr. Kenward, of Birmingham, giving particulars of an anthropometric laboratory established at Birmingham, like that of Mr. Francis Galton at South Kensington.

SECOND CONFERENCE, AUGUST 9.

The Corresponding Societies Committee were represented by Professor R. Meldola (Chairman) and Messrs. Symons, Whitaker, Cuthbert Peek, Garson, Poulton, Rev. Canon Tristram, Sir Rawson Rawson, and T. V. Holmes (Secretary).

The Chairman suggested that in future some subject in which the delegates generally were interested, such as the management of local museums, the relations of County Councils to technical instruction, or the working of the Technical Education Acts, should be brought before the Conference in the form of a short paper to serve as a basis of discussion. This proposition met with general approval.

Mr. Symons mentioned that he had arranged with Mr. Griffith that delegates on the first day of the meeting of the British Association should be supplied with copies of the reports on subjects in which they were interested. This would give them longer time than they had at present to make themselves acquainted with the work which was being done.

Section A.

Underground Waters.—Mr. Symons said that some remarks had been made on the circulation of underground waters, and he wished that when wells were sunk the temperature, as well as the depth, of the water should be taken. It was very easily done, as they had only to send down a thermometer in the bucket, and bring up the bucket full of water. If such observations were made at the same hour of the day throughout the year they would be of very considerable use. The depth of water in a well should always be measured from the surface of the ground.

Mr. Whitaker said that it was also important that the variation in the depth of water in a well should be recorded.

Section D.

Disappearance of Native Plants.—Mr. Mark Stirrup read a letter written by Mr. Leo Grindon dealing with the disappearance of native plants during the last fifty years in the district within a radius of fifteen miles round Manchester. The wide, uncultivated moorlands (remarked Mr. Grindon) remained unchanged. Harsh and wiry grasses, a few ferns, heather, whortleberry, and crowberry still renewed themselves perennially there; and in the flat country which had been and remained agricul-

tural or pastoral there was but little change. The changes which had occurred were referable almost wholly to the enterprise and activity of the landowners, who had converted peat-mosses and sandy wastes into land profitable for agriculture or even for building purposes. Hence the disappearance of *Gentiana pneumonanthe* and *Osmunda*, with other less conspicuous moss and moor plants. However, in other quarters there is still no lack of the cotton sedge, the Lancashire asphodel, and the *Erica tetralix*. But the dye-polluted streams are forsaken by the forget-me-nots and other water-loving plants, and many ponds within five or six miles of the town have been drained or filled up, or converted into lakes for the adornment of pleasure grounds. These changes have involved the loss of such plants as the *Stratiotes*, the *Myriophyllum*, and various rare sedges, the *Carex elongata*, for instance, once abundant. Fifty years ago the little dells, locally called 'cloughs,' were noted for their curious botany. Mere Clough, near Prestwich Mere, once grew in plenty the *Calamagrostis lanceolata*, *Chrysosplenium alternifolium*, *Geum rivale*, and various shade-loving carices. Now all are gone, partly through the felling of the trees and drying of the soil, partly because the clough being now a thoroughfare, much trampling down and destruction are done by the reckless and unobservant.

Coming to the wilful and deliberate destruction of plants, Mr. Leo Grindon remarked that the professed botanists and simple collectors of specimens for the herbarium were but little to blame. The Manchester flora could not be said to have ever included species existing scarcely anywhere else, and the local botanists had therefore but little to answer for. Even the 'Field Naturalists,' who had been an organised body more than thirty years, could not be charged with wasteful gathering. Many of the members took home handfuls of wild flowers, but the plants taken were such as would never be missed. By whom, then, was the mischief done? The herb-doctors or 'medical botanists' had caused much destruction of plants supposed to have medicinal value, such as the *Erythræa centaurium*. They were often to be seen in the season returning home with plants under their arms which had been pulled up by the roots just as they were coming into bloom. Another destructive agency was that of the dealers in roots for the garden. One of them had once asked him to name a locality where he could dig up from 300 to 500 roots of a certain rather favourite fern, but without obtaining a reply. Another dealer brought with him a basket and trowel in order to bring away 'all there was' from a particular spot, which was consequently not visited that afternoon, the botanical guide of the party having become aware of the dealer's plan. Besides ferns, dealers dug up immense numbers of primroses, cowslips, and oxlips, and had greatly diminished their numbers. Thus the mischief done to the local flora was partly due to the progress of agriculture and manufactures and the increase in building, partly to the rapacity of the dealers in ferns and other plants.

Mr. Mark Stirrup added that he could confirm Mr. Leo Grindon's remarks from his own experience of the disappearance of ferns and primroses in the neighbourhood of Manchester within the last fifteen or twenty years. In one case he remembered that a gentleman sent a horse and cart to a certain spot where the *Osmunda* grew, and removed all the specimens he could find.

Mr. Sowerbutts thought it would be well for field naturalists' clubs to keep the exact localities in which rare plants grew for their own

information only. He thought that Mr. Leo Grindon was himself largely responsible for the eradication of rare plants around Manchester, as he had published a volume called 'Walks about Manchester' in which their habitats were described.

Mr. Coates (Perthshire) said their naturalists' field club, in publishing accounts of excursions or notices in papers of rare plants, only indicated generally where these were to be found; and Mr. W. Gray said that the Belfast Naturalists' Field Club acted in a similar way.

As regards the extermination of native plants, Canon Tristram added that the neighbourhood of Durham was once one of the richest botanical districts in the north of England, but that during his lifetime some of the most interesting species of plants, and also some of the most interesting species of butterflies and moths, had been exterminated. The 'lady's slipper' had disappeared. He had seen advertisements in the 'Gardener's Chronicle' offering half a guinea for that plant, the advertisement always stating where it was supposed to be obtainable. The late Rowland Burton had remarked to him that the half-dozen plants of 'lady's slipper' on his property cost him more to protect them than his pheasants did. The butterfly, *Erebia blandina*, was no longer to be found in the county of Durham. The rarer orchids and the hart's-tongue fern were being exterminated in many districts, but public opinion had been thoroughly efficient in the preservation of the ferns planted close to the walks on the banks of the river at Durham, and he looked to the formation of a public opinion as the best means of preserving plants elsewhere. Field clubs should make their members feel that their first object was to preserve, not to destroy.

Mr. Mark Stirrup said that the preservation of rarities was enjoined by the Manchester societies. As regards the observations of Mr. Sowerbutts, he did not think the plants mentioned were such as the dealers prized.

Preservation of Wild Birds' Eggs.—The Rev. E. P. Knubley (Leeds) moved the following resolution, which was seconded by Mr. E. B. Poulton (Oxford) and agreed to:—

'The Conference of Delegates, having heard of the threatened extermination of certain birds, as British breeding species, through the destruction of their eggs, deprecates the encouragement given to dealers by collectors through their demands for British-taken eggs, and trusts that the Corresponding Societies will do all that lies in their power to interest and influence naturalists, landowners, and others in the preservation of such birds and their eggs.'

On this subject Canon Tristram also spoke, and put in a strong plea for the preservation of birds of prey, pointing to the case of the mice plague in Dumfries and Lanark shires as a result of destroying the balance of nature by wholesale killing of birds of prey. The resolution brought forward by Mr. Knubley was cordially adopted by the meeting.

Local Museums.—The Rev. Canon Tristram (Durham) next addressed the delegates on the question of making their field clubs more useful. He strongly advocated that these clubs should combine natural history, archæology, and geology; and that their function should be, not to destroy, but to preserve all that was rare and curious in a district. Lately their field excursions in many places had been too much of picnic parties. On the subject of local museums, the Canon argued that, as a rule, these should only contain objects of local interest, and he suggested

that an approach should be made to the County Councils in order to get assistance for forming museums and keeping them in order. Many museums had gone to utter decay from the want of an endowment. Those at Newcastle, York, Manchester, Liverpool, and Norwich were all endowed. On the other hand, that at Lynn, in Norfolk, for want of an endowment was mouldering away. Local societies should try to promote interest in the local museum, so that they might raise an endowment fund, by the help of wealthy residents and the County Council, in order to keep a curator, without whom a museum was of little use.

SECTION H.

Proposed Ethnological Survey.—Mr. Brabrook said he was deputed by the Committee of Section H to ask the approval and assistance of the Corresponding Societies in the organisation of an Ethnological Survey of the United Kingdom. The attempt to organise this survey was being made by a committee of delegates from the Society of Antiquaries, the Anthropological Institute, and the Folklore Society. These delegates represented the various points of view of the societies electing them, and he felt sure of the sympathy of the Corresponding Societies in this movement. The matter was one which would not brook delay; every year tended to increase its difficulties, and if postponed much longer it would become impossible to proceed at all. Several of the Corresponding Societies had been working in this direction, and it would only be necessary for them to follow the instructions which would be sent down to them by the Ethnological Survey Committee when it began its labours. From the reports of the Corresponding Societies he learnt that thirty-three of them had been at work on this subject during the last eight years, and that during that period 100 members of these societies had contributed papers on it to the 'Proceedings.' He would urge them, therefore, to look at men from the three points of view indicated. He agreed with the Rev. Canon Tristram that field clubs should include archæology among their subjects of study. It was absurd to look at man merely from the natural history point of view, and ignore his archæological aspects.

Preservation of Ancient Remains.—Mr. Whitaker said that in the Hampshire district it had been found that a remonstrance against the destruction of ancient remains usually had a good effect. Proprietors often did not know the interest and value of antiquities on their estates, but cared for them after they became aware of it. Certain Government departments sometimes needed similar education. One of the best Hampshire tumuli was almost destroyed recently in the making of a rifle butt.

Mr. W. Gray remarked that, in Ireland, Government was very anxious to preserve all monuments, and that the Naturalists' Field Club of Belfast not only did its best to keep them uninjured but also photographed them. He had pleasure in exhibiting some of these photographs, copies of which might be obtained by anyone interested in geology or archæology on application to the local secretary.

The Chairman was sure the Corresponding Societies would do their best to assist Mr. Brabrook, and he would ask that gentleman if he would point out in what way the societies could best help him.

Mr. Brabrook said it was a little difficult to do so because the

material was so abundant. He had there the result of an archæological survey of Kent and a scheme applicable to the county of Gloucester. There were also the books prepared by the Anthropological Institute and the Folklore Society. All these works gave instructions for working in the way desired. But their bulk made it necessary that the Committee should devise something smaller for the exploration, and that would be the first of its labours. The Committee would then send a pamphlet containing the needed suggestions to every Corresponding Society.

Railway Facilities.—Mr. Sowerbutts thought better terms might be obtained from the railway companies for delegates and others travelling to meetings of the British Association. The Chairman and Mr. Symons promised to represent the matter to the Council of the Association. The Corresponding Societies Committee now have to report that in accordance with this promise a strong committee of the Council was appointed, on the motion of Professor Meldola, and a representation made to the authorities at the Clearing House, but no concession could be obtained beyond what is allowed by Traffic Regulation No. 30, viz., 'Members are allowed during a Meeting to take railway tickets at the town where the Meeting is held at a single fare for the double journey to places within a distance of fifty miles.'

The Committee recommend the retention of all the societies at present on the list, with the exception of the Barnsley Naturalists' and Scientific Society, which had not filled in and returned the schedule at the time of the Meeting of the Committee.

In order to make the publications of the Corresponding Societies available for reference, the Committee decided to have them bound. Accordingly Mr. Topley and Mr. T. V. Holmes (Secretary) were instructed to examine them and to select for binding some of the more complete and valuable. Fifty-eight volumes have already been bound and placed on the shelves of the Association. Others will be added from time to time as the amount of the grant available for this purpose may allow.

The Corresponding Societies of the British Association for 1893–94.

[An asterisk (*) indicates that the Society was represented at the Conference of Delegates at Edinburgh.]

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Bath Natural History and Antiquarian Field Club, 1855	Bath N. H. A. F. C.	W. W. Martin, Royal Literary and Scientific Institution, Bath	100	5*s.*	10*s.*	Proceedings, annually.
Bedfordshire Archæological and Natural History Society, 1875	Beds. N. H. Soc. F. C.	Bedfordshire General Library, Harper Street, Bedford. T. Gwyn Elger, F.R.A.S.	900	None	25*s.* and 10*s.* 6*d.*	Transactions, occasionally.
*Belfast Natural History and Philosophical Society, 1821	Belfast N. H. Phil. Soc.	Museum, College Square. R. M. Young, B.A.	277	None	1*l.* 1*s.*	Report and Proceedings, annually.
*Belfast Naturalists' Field Club, 1863	Belfast Nat. F. C.	Museum, College Square. R. Lloyd Praeger, B.E., and F. J. Bigger	402	None	5*s.*	Report and Proceedings, annually.
Birmingham Natural History and Microscopical Society, 1858	Birm. N. H. M. Soc.	W. P. Marshall, Mason College, Birmingham	192	None	21*s.* and 10*s.* 6*d.*	'Midland Naturalist,' monthly.
Birmingham Philosophical Society	Birm. Phil. Soc.	T. W. Bridge and J. Landon, Medical Institute, Edmund Street, Birmingham	109	None	1*l.* 1*s.*	Proceedings, annually.
*Bristol Naturalists' Society, 1862	Bristol Nat. Soc.	University College, Bristol. M. Percy Leonard	214	5*s.*	10*s.*	Proceedings, annually.
*Burton-on-Trent Natural History and Archæological Society, 1876	Burt. N. H. Arch. Soc.	G. Morland Day, 8 Alexandra Road, Burton-on-Trent	231	None	5*s.*	Annual Report. Transactions occasionally.
Cardiff Naturalists' Society, 1867	Cardiff Nat. Soc.	Walter Cook, 98 St. Mary Street, Cardiff	390	None	10*s.* 6*d.*	Report and Transactions, half-yearly
Chester Society of Natural Science and Literature, 1871	Chester Soc. Nat. Sci.	Grosvenor Museum, Chester. G. R. Griffith	660	None	5*s.*	Annual Report. Proceedings occasionally.
*Chesterfield and Midland Counties Institution of Engineers, 1871	Chesterf. Mid. Count. Inst.	Stephenson Memorial Hall. W. F. Howard, 15 Cavendish Street, Chesterfield	282	1*l.* 1*s.*	Members 31*s.* 6*d.*; Associates and Students 20*s.*	Transactions of Federated Institution of Mining Engineers, about every two months.
Cornwall, Mining Association and Institute of, 1859	Cornw. Min. Assoc. Inst.	William Thomas, C.E., F.G.S., Penelvan, Camborne	382	10*s.* 6*d.*	Minimum, 10*s.* 6*d.*	Transactions, annually.
Cornwall, Royal Geological Society of, 1814	Cornw. R. Geol. Soc.	G. B. Millett, Penzance	100	None	1*l.* 1*s.*	Report and Transactions, annually.
*Croydon Microscopical and Natural History Club, 1870	Croydon M. N. H. C.	Public Hall, Croydon. T. D. Aldous	276	None	10*s.*	Proceedings and Transactions, annually.
Cumberland and Westmorland Association for the Advancement of Literature and Science, 1876	Cumb. West. Assoc.	J. B. Bailey, 28 Eaglesfield Street, Maryport	755	None	6*s.*	Transactions, annually.
*Dorset Natural History and Antiquarian Field Club, 1875	Dorset N. H. A. F. C.	N. M. Richardson. Montevideo, Chickerel, Weymouth	291	None	10*s.*	Proceedings, annually.
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	Dum. Gal. N. H. A. Soc.	Dr. E. J. Chinnock, Grey Friars', Dumfries	193	2*s.* 6*d.*	5*s.*	Transactions and Journal of Proceedings, annually.
*East Kent Natural History Society, 1857	E. Kent N. H. Soc.	39 High Street, Canterbury. Frank Baker	75	None	Ladies 5*s.*; Gentlemen 10*s.*	'South Eastern Naturalist,' occasionally.
*East of Scotland Union of Naturalists' Societies, 1884	E. Scot. Union	William D. Sang, 28 Whyte's Causeway, Kirkcaldy, N.B.	9 Societies, 946 Membs.	None	Assessment of 4*d.* per member	Proceedings, generally annually.

		Edinburgh				
*Essex Field Club, 1880	Essex F. C.	William Cole, 7 Knighton Villas, Buckhurst Hill, Essex	450	10s. 6d.	15s.	'Essex Naturalist,' monthly.
*Federated Institution of Mining Engineers	Fed. Inst. Min. Eng.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	1,600	None	None	Transactions, about every two months.
*Glasgow, Geological Society of, 1858	Glasgow Geol. Soc.	J. B. Murdoch, Capelrig, Mearns, Glasgow	250	None	10s.	Transactions, annually.
Glasgow, Natural History Society of, 1851	Glasgow N. H. Soc.	D. A. Boyd and John Cairns, jun., 207 Bath Street, Glasgow	307	7s. 6d.	7s. 6d.	Proceedings and Transactions, annually.
Glasgow, Philosophical Society of, 1802	Glasgow Phil. Soc.	John Mayer, 207 Bath Street, Glasgow	675	1l. 1s.	1l. 1s.	Proceedings, annually; occasional papers.
*Hampshire Field Club, 1885	Hants F. C.	Hartley Institution, Southampton. W. Dale, F.G.S.	250	None	7s. 6d.	Proceedings, annually.
*Hertfordshire Natural History Society and Field Club, 1875	Herts N. H. Soc.	Dr. J. Morison, F.G.S., St. Albans	260	10s.	10s.	Transactions, quarterly.
Holmesdale Natural History Club, 1857	Holmesdale N. H. C.	A. J. Crosfield, Carr End, Reigate	78	10s.	10s.	Proceedings, every two or three years.
*Inverness Scientific Society and Field Club, 1875	Inverness Sci. Soc.	F. A. Black, 16 Union Street, Inverness	173	None	5s. and 2s.	Transactions, occasionally.
Ireland, Royal Geological Society of, 1831	R. Geol. Soc. Ireland	Prof. W. J. Sollas, F.R.S., Trinity College, Dublin	140	None	1l. 1s.	Journal, generally annually.
Ireland, Statistical and Social Inquiry Society of, 1847	Stat. Soc. Ireland	W. F. Bailey, J. Pim and W. Lawson, 35 Molesworth Street, Dublin	104	None	1l.	Journal, annually.
Leeds Geological Association, 1874	Leeds Geol. Assoc.	Wm. Lower Carter, F.G.S., Meanwood, Leeds	123	None	5s.	Transactions, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Leeds Nat. C. Sci. Assoc.	80 Municipal Buildings, Leeds. H. B. Wilson and Arthur Walker	224	None	6s.	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Leicester Lit. Phil. Soc.	J. M. Gimson, Town Museum, Leicester	343 Membs. & Associates	None	Members 1l. 1s.; Associates 10s. 6d.	Transactions, quarterly.
Liverpool Engineering Society, 1875	Liv'pool E. Soc.	R. C. F. Annett, Royal Institution, Liverpool	240	None	Resident 1l. 1s. Non-Res. 10s. 6d.	Transactions, annually.
*Liverpool Geographical Society, 1891	Liv'pool Geog. Soc.	Staff Com. Phillips, R.N., 6A The Temple, Dale Street, Liverpool	340	None	1l. 1s.	Uncertain.
Liverpool Geological Society, 1858	Liv'pool Geol. Soc.	Royal Institution. H. C. Beasley	49	None	1l. 1s.	Proceedings, annually.
Liverpool, Literary and Philosophical Society of, 1812	Liv'pool Lit. Phil. Soc.	Royal Institution. H. Longuet-Higgins, 7 Sandringham Drive, Liverpool	199	None	1l. 1s.	Proceedings, annually.
Liverpool Microscopical Society, 1868	Liv'pool Mic. Soc.	Royal Institution. Andrew T. Smith, jun.	118	1l. 1s.	10s. 6d.	Report, annually.
*Malton Field Naturalists' and Scientific Society, 1879	Malton F. N. Sci. Soc.	Thomas J. Blanche, Malton, Yorkshire	86	None	5s.	Report, occasionally.
*Man, Isle of, Natural History and Antiquarian Society, 1879	I. of Man N. H. A. Soc.	P. M. C. Kermode, Hillside, Ramsey, Isle of Man	135	2s. 6d.	Gentlemen 6s.; Ladies 3s.	Yn Lioar Manninagh, quarterly
*Manchester Geographical Society, 1885	Manch. Geog. Soc.	Eli Sowerbutts, F.R.G.S., 44 Brown Street, Manchester	850	None	Members 1l. 1s.; Associates 10s. 6d.	Journal, quarterly.
*Manchester Geological Society, 1838	Manch. Geol. Soc.	Mark Stirrup, F.G.S., 36 George Street, Manchester	222	None	1l.	Transactions, eight or nine parts per annum.
Manchester Statistical Society, 1833	Manch. Stat. Soc.	63 Brown Street, Manchester. Francis E. M. Beardsall and T. A. Scholes	166	10s. 6d.	10s. 6d.	Transactions, annually.
Marlborough College Natural History Society, 1864	Marlb. Coll. N. H. Soc.	Marlborough College. E. Meyrick.	310	1s. 6d.	3s. and 5s.	Report, annually.

Selected List of Societies, &c. (*continued*).

Full Title and Date of Foundation	Abbreviated Title	Head-quarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
*Midland Union of Natural History Societies, 1877	Mid. Union	Dr. T. Stacey Wilson, Wyddrington, Edgbaston, Birmingham, and W. Wickham King, Pedmore House, Stourbridge	15 Societies	—	3*d*. per Member	'Midland Naturalist,' monthly.
*North of England Institute of Mining and Mechanical Engineers, 1852	N. Eng. Inst.	M. Walton Brown, Neville Hall, Newcastle-upon-Tyne	691	None	21*s*. and 42*s*.	Transactions of Federated Institution of Mining Engineers, about every two months.
*North Staffordshire Naturalists' Field Club and Archæological Society, 1865	N. Staff. N. F. C. A. Soc.	Rev. T. W. Daltry, M.A., Madeley Vicarage, Newcastle, Staffs.	393	5*s*.	5*s*.	Report and Transactions, annually.
*Northamptonshire Natural History Society and Field Club, 1876	N'ton. N. H. Soc.	H. N. Dixon, East Park Parade, Northampton	200	None	10*s*.	Journal, quarterly.
Nottingham Naturalists' Society, 1852	Nott. Nat. Soc.	Nottingham Institute, 9 Shakespeare Street. F. R. Jackson	140	None	5*s*.	Transactions and Report, annually.
Paisley Philosophical Institution, 1808	Paisley Phil. Inst.	J. Gardner, 3 County Place, Paisley	395	5*s*.	7*s*. 6*d*.	Report, annually.
Penzance Natural History and Antiquarian Society, 1839	Penz. N. H. A. Soc.	G. F. Tregelles, 3 Market Place, Penzance	92	None	10*s*. 6*d*.	Report and Transactions, annually.
*Perthshire Society of Natural Science, 1867	Perths. Soc. N. Sci.	Tay Street, Perth. S. T. Ellison	298	2*s*. 6*d*.	5*s*. 6*d*.	Transactions and Proceedings, annually.
*Rochdale Literary and Scientific Society, 1878	Rochdale Lit. Sci. Soc.	J. Reginald Ashworth, 20 King Street South, Rochdale	258	None	6*s*.	Transactions, occasionally.
Rochester Naturalists' Club, 1878	Rochester N. C.	John Hepworth, Union Street, Rochester	179	None	3*s*. 6*d*., 5*s*., and 10*s*.	'Rochester Naturalist,' quarterly.
*Somersetshire Archæological and Natural History Club, 1849	Som'setsh. A. N. H. Soc.	The Castle, Taunton. F. T. Elworthy	570	10*s*. 6*d*.	10*s*. 6*d*.	Proceedings, annually.
South African Philosophical Society, 1877	S. African Phil. Soc.	W. H. Finlay, Royal Observatory, Cape Town	68	None	2*l*.	Transactions, annually.
South London Microscopical and Natural History Club, 1871	S. London M. N. H. C.	Brixton Hall, Acre Lane, Brixton. H. Groves	102	None	10*s*.	Report, annually.
*Tyneside Geographical Society, 1887	Tyneside Geog. Soc.	Geographical Institute, Barras Bridge, Newcastle-on-Tyne. G. E. T. Smithson	1,000	None	10*s*.	Journal, half-yearly.
*Warwickshire Naturalists' and Archæologists' Field Club, 1854	Warw. N. A. F. C.	W. G. Fretton, F.S.A., Hearsall Terrace, Chapel Fields, Coventry	82	2*s*. 6*d*.	5*s*.	Proceedings, annually.
*Woolhope Naturalists' Field Club, 1851	Woolhope N. F. C.	Woolhope Club Room, Free Library, Hereford. H. Cecil Moore	195	10*s*.	10*s*.	Transactions, biennially.
Yorkshire Geological and Polytechnic Society, 1837	Yorks. Geol. Poly. Soc.	James W. Davis, F.G.S., Chevinedge, Halifax	250	None	13*s*.	Proceedings, annually.
*Yorkshire Naturalists' Union, 1861	Yorks. Nat. Union	W. Denison Roebuck, F.L.S., Sunny Bank, Leeds; Rev. E. P. Knubley, M.A., Staveley Rectory, Leeds	462 and 2,518 Associates	None	10*s*. 6*d*.	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1822	Yorks. Phil. Soc.	Museum, York. T. S. Noble, F.G.S.	350	None	2*l*.	Report, annually.

... important Papers, and especially those referring to Local Scientific Investigations, published by the above-named Societies during the year ending June 1, 1893.

** This catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—Mathematical and Physical Science.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Andson, Rev. W.	Mr. Aitken's Theory of Dew	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8.	5	1893
" "	Meteorology of Dumfries for 1891	" " "	"	"	41	"
Ashworth, J. R.	Seasonable Variations of Temperature at Spring Mill Reservoir	Rochdale Lit. Sci. Soc.	"	III.	65	"
Brown, J.	Some Elementary Facts regarding the Foci of Lenses, with special reference to Dallmeyer's New Tele-photographic Lens	Glasgow Phil. Soc.	*Proc.*	XXIII.	225	1892
Burder, Dr. G. F.	Rainfall at Clifton in 1891	Bristol Nat. Soc.	"	VII.	13	"
" "	Rainfall and Floods	" "	"	"	19	"
Clark, J. E.	Notes on York Meteorology for 1892	Yorks. Phil. Soc.	*Report*	For 1892	33	1893
Dickinson, J.	On Outbursts of Soft Coal and Gas in the Royley Seam, Broad Oak Colliery, Ashton-under-Lyne	Manch. Geol. Soc.	*Trans.*	XXII.	239	"
Dixon, H. N.	Phenological Observations, 1891	N'ton. N. H. Soc.	*Journal*	VII.	92	1892
Dowker, G.	Our Climate	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	84	1893
Finlay, W. H.	The Progress of Astronomy during the last Ten or Twelve Years	S. African Phil. Soc.	*Trans.*	V.	xxv	"
" "	The Progress of Astronomy, 1887–89	" "	"	"	liii	"
" "	The Orbit of Comet 1886	" "	"	"	234	"
" "	Approximate Tide-constants for Table Bay and Algoa Bay	" "	"	"	253	"
Gurnell, J.	On the Connection between Atmospheric Pressure and Earth Movements	Leeds Geol. Assoc.	"	VII.	34	1892
Guthrie, Prof.	Sea Levels in South Africa from Barometric Observations	S. African Phil. Soc.	"	V.	318	1893
Hopkinson, J.	Report on the Rainfall in Hertfordshire in 1891	Herts N. H. Soc.	"	VII.	53	1892
" "	Meteorological Observations taken at the Grange, St. Albans, during the year 1891	" "	"	"	69	1893

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Horsley, Col. W. H.	Report on Temperature of Air and Water as taken at the River Stour, Canterbury, during the year 1890	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	69	1893
Howard, A. G.	The Winter Storms of South Africa, illustrating the Value of Cape Point as a Warning Station	S. African Phil. Soc.	*Trans.*	V.	203	,,
,, ,,	The Storms of South Africa	,, ,,	,,	,,	235	,,
,, ,,	The Barometer: Its Reduction to Sea Level	,, ,,	,,	,,	259	,,
Jones, M. V.	The Causes of Spontaneous Combustion of Coal, and Prevention of Explosions on Shipboard	Fed. Inst. Min. Eng.	,,	3	789	1892
Lodge, Prof. O. J.	Thought Transference: An Application of Modern Thought to Ancient Superstitions	Liv'pool Lit. Phil. Soc.	*Proc.*	XLVI.	127	,,
Lupton, Prof. A.	Spontaneous Combustion in Coal Mines	Fed. Inst. Min. Eng.	*Trans.*	4	481	1893
Markham, C. A.	Meteorological Reports	N'ton. N. H. Soc.	*Journal*	VII.	26, 73, 116, 147	1892
Rintoul, D.	Observations of Temperature at Clifton College in 1891	Bristol Nat. Soc.	*Proc.*	XII.	14	,,
Smith, W. A.	The Scientific Cultivation of the Senses	Glasgow Phil. Soc.	,,	XXIII.	67	,,
Southall, H.	The Floods of May, 1886, and the Weather of the previous Winter	Woolhope N. F. C.	*Trans.*	1886–1889	44	,,
Stainier, X.	Temperature Observations in a Deep Coal-pit Sinking in Belgium, with Analysis and Temperature of a Spring of Water at a Depth of 3,773 feet	Manch. Geol. Soc.	,,	XXII.	204	1893
Stuart, M. G.	Report on the Returns of Rainfall	Dorset N. H. A. F. C.	*Proc.*	XIII.	239	1892
Thomson, J. S.	Some old Sun-dials of the District	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	54	1893
Tyndall, W. H.	Meteorological Notes, Redhill, 1889	Holmesdale N. H. C.	*Proc.*	For 1890-92	1	,,
,, ,,	,, ,, 1890	,, ,,	,,	,,	23	,,
,, ,,	,, ,, 1891	,, ,,	,,	,,	71	,,
Wells, J. G.	Weather Report for 1891	Burt. N. H. Arch. Soc.	*Trans.*	For 1891-92	15	1892
,, ,,	,, ,, 1892	,, ,,	,,	For 1892-93	—	1893
Wells, J. G., & others	Phenological Observations for 1891	,, ,,	,,	For 1891-92	13	1892
Wilmer, H. C.	The Relation of the Sand Dune Formation on the South-west Coast of Africa to the Local Wind Currents	S. African Phil. Soc.	,,	V.	326	1893

deacon		Rochdale Lit. Sci. Soc.	,,	III.	57	,,
Woods, C. R.	On some Photographs of Lightning Flashes	S. African Phil. Soc.	,,	V.	298	,,
,, ,,	Photographs of Lightning Flashes taken September 18, 1888	,, ,,	,,	,,	303	,,

Section B.—CHEMISTRY.

Burford, S. F.	Starch	Leicester Lit. Phil. Soc.	*Trans.*	III.	10	1892
Fawsitt, C. A.	Memoir of the late Professor Dittmar, LL.D., F.R.S., F.R.S.E.	Glasgow Phil. Soc.	*Proc.*	XXIII.	303	,,
Ferguson, Prof. J.	On the First Edition of the Chemical Writings of Democritus and Synesius: Part III.	,, ,,	,,	,,	153	,,
Fryer, Dr. A. C.	Analysis of Volcanic Ashes from the Volcanic Eruption at Krakatoa in 1883	Bristol Nat. Soc.	,,	VII.	44	,,
Howard, F. T.	Stages in Crystallisation	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	23	1893
Marloth, Dr. R.	On the Adulteration of Brandy	S. African Phil. Soc.	*Trans.*	V.	247	,,
Milne, Mr.	Nitrate of Soda	Inverness Sci. Soc.	,,	III.	58	,,
Orsman, W. J.	The Detonation of High Explosives by Percussion	N. England Inst.	,,	3	574	1892
Stenhouse, T.	Coal Smoke	Rochdale Lit. Sci. Soc.	,,	III.	13	1893
Swan, A. P.	Milk and its Ferments	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	133	,,
Thompson, W.	On Acid Pumps	Bristol Nat. Soc.	*Proc.*	VII.	54	1892
Thomson, W. E. F.	Fogs: A Review of our present Position regarding them	Glasgow Phil. Soc.	,,	XXIII.	257	,,
Thorpe, Prof. T. E.	The Phenomena of Coal Dust Explosions	Fed. Inst. Min. Eng.	*Trans.*	3	681	,,
Thresh, Dr. J. C.	The Shallow and Deep Well Waters of Essex	Essex F. C.	*Essex Naturalist*	VII.	28	1893

Section C.—GEOLOGY.

Aitken, Dr.	Notes on the Abriachan District	Inverness Sci. Soc.	*Trans.*	III.	162	1893
Batten, E. C.	The Centenary of William Smith, LL.D., the Father of English Geology	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVIII.	351	1892
Beasley, H. C.	The Bunter Conglomerate near Cheadle, Staffordshire	Liv'pool Geol. Soc.	,,	VI.	439	,,
Beasley, H. C., and J. Lomas	Some East and West Faults at Caldy Grange	,, ,,	,,	,,	413	,,

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Bedford, J. E.	Evidences of Glacial Action in the Leeds District	Leeds Geol. Assoc.	*Trans.*	VII.	29	1892
Bell, A.	Notes on a Post-Tertiary Deposit in Sussex	Yorks. Phil. Soc.	*Report*	For 1892	58	1893
Bell, T.	Section of Strata sunk through in Deaf Hill Colliery, Co. Durham	Manch. Geol. Soc.	*Trans.*	XXII.	191	"
Bennett, F. J.	Notes on the Occurrence of Chalk Rock near Marlborough	Marlb. Coll. N. H. Soc.	*Report*	41	60	"
Brodie, Rev. P. B.	Reminiscences of a Search for Fossil Insects—where and how to find them	Warw. N. A. F. C.	*Proc.*	37	21	"
Brownridge, C.	The North Coast of Antrim	Leeds Geol. Assoc.	*Trans.*	VII.	9	1892
Burton, W.	The Manufacture of China and Earthenware	Fed. Inst. Min. Eng.	"	4	112	1893
Caldwell, G.	Fossil Plants from the Cannel of Wigan Four Feet Mine	Manch. Geol. Soc.	"	XXII.	211	"
Carter, W. L.	Notes on the Bernese Oberland	Leeds Geol. Assoc.	"	VII.	22	1892
" "	A fine Carboniferous Tree in the Ganister Beds, Meanwood, Leeds	" "	"	"	51	"
" "	Reports of Field Excursions	" "	"	"	53	"
Cheetham, W.	Geologists in the Lake District	" "	"	"	20	"
Clay, Stirrup, and Wild, Messrs.	Globular Concretions from the Coal Measures of Lancashire	Manch. Geol. Soc.	"	XXII.	66	"
Coates, H.	Report on the Geology of the Cuttings of the Crieff and Comrie Railway	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	257	"
" "	Presidential Address: Denudation	" "	" "	11	cxxxviii	"
Coates, H., and P. Macnair	The Old Red Sandstone of Perthshire	" "	" "	I.	235	"
Cole, Rev. E. M.	Erosion of the Yorkshire Coast	Yorks. Nat. Union	*The Naturalist*	For 1893	142	1893
Colenutt, G. W.	The Bembridge Limestone of the Isle of Wight	Hants F. C.	*Proc.*	II.	167	"
Collins, J. H.	A Working List of the Palæozoic Fossils of Cornwall	Cornw. R. Geol. Soc.	*Report and Trans.*	XI.	421	"
Crick, W. D., and C. D. Sherborn	On some Liassic Foraminifera from Northamptonshire: Part II. The Leda ovum Beds of the Upper Lias	N'ton. N. H. Soc.	*Journal*	VII.	67	1892
Crosskey, Dr. H. W.	The Clava Shell Bed	Inverness Sci. Soc.	*Trans.*	III.	277	1893
Cumming, L.	Mud Avalanches	Liv'pool Geol. Soc.	*Proc.*	VI.	393	1892

Dawkins, Prof. W. Boyd	On the Coalfields of New South Wales	Manch. Geol. Soc.	*Trans.*	XXII.	159	1893
De Rance, C. E.	On the Relation of Geology to the Population of England and Wales	" "	"	"	55	1892
Dickson, E.	Mud Avalanches	Liv'pool Geol. Soc.	*Proc.*	VI.	387	"
" "	Notes on the Devon Coast Section from Exmouth to Sidmouth	" "	"	"	407	"
Dowker, G.	Report on Society's Excursion to Reculver	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	71	1893
" "	Thoughts in a Gravel Pit	" "	" "	"	72	"
Dunlop, R.	Note on a 'Wash-out' in a Shallow Pit of the Drumshangie Coal Co., near Airdrie	Glasgow Geol. Soc.	*Trans.*	IX.	320	"
Elliott, Rev. W.	The Geology of the District of Old Radnor	Woolhope N. F. C.	"	1886–1889	207	1892
Fitzpatrick, J. J.	Further Notes on the Deepdale Bone Cave, near Buxton	Liv'pool Geol. Soc.	*Proc.*	VI.	447	"
Forsyth, Dr. D.	The Geology of the Carsphain District of Kirkcudbrightshire	Leeds Geol. Assoc.	*Trans.*	VII.	15	"
French, J.	On some Plateau Deposits at Felstead and Stebbing	Essex F. C.	*Essex Naturalist*	VI.	130	"
Gardiner, E. J. L.	Note on the Fish Remains from the Old Red Sandstone of Portishead	Bristol Nat. Soc.	*Proc.*	VII.	34	"
Gilford, W.	Are there Coalfields in Surrey?	Holmesdale N. H. C.	"	For 1890-92	42	1893
Goodchild, J. G.	Observations on the New Red Series of Cumberland and Westmorland, with especial reference to Classification	Cumb. West Assoc.	*Trans.*	XVII.	1	1892
" "	Notes on the Water Supply of Edenside	" "	"	"	43	"
" "	Notes on the Glacial Phenomena of Upper Ribblesdale	Yorks. Nat. Union	*The Naturalist*	For 1892	241	"
Greenwell, G. C.	On the Probability of Coal being found South of the Mendips, in Somersetshire	Manch. Geol. Soc.	*Trans.*	XXI.	596	"
Gresley, W. S.	Geological History of the Rawdon and the Boothorpe Faults in the Leicestershire Coalfields	Chesterf. Mid. Count. Inst.	"	4	431	1893
Grigor, Dr.	Cup-marked Stones	Inverness Sci. Soc.	"	III.	43	"
Grundy, J.	How and What to Observe in and about Mines	Manch. Geol. Soc.	"	XXII.	113	1892
Halse, E.	Notes on the Occurrence of Manganese Ore near Mulegé, Baja California, Mexico	N. Eng. Inst.	"	3	934	"
" "	Notes on the Occurrence of Manganese Ore near the Arenigs, Merionethshire	" "	"	3 4	940 167	"
Hambly, W.	The Gold Fields of South Africa	Cornw. Min. Assoc. Inst.	"	III.	68	"

Section C.—GEOLOGY (*continued*).

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Hamilton, J. P.	Witwatersrand Gold Field, Transvaal, South Africa	Ch'sterf. Mid. Count. Inst.	*Trans.*	3	857	1892
" "	Notes on the Natal Coalfields	" "	"	"	874	"
Harker, A.	Bibliography of Papers on the Geology and Palæontology of the North of England, 1891	Yorks. Nat. Union	*The Naturalist*	For 1892	219	"
" "	Norwegian Boulders in Holderness	" "	" "	For 1893	1	1893
Harrison, Rev. S. N.	Geological Report, 1891–92	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	II.	375	1892
Hewitt, W.	Presidential Address: The Earth in its Cosmical Relations	Liv'pool Geol. Soc.	*Proc.*	VI.	349	"
Hinxman, L. W.	The Geology of the Country between Huntly and Kildrummie Castle	Inverness Sci. Soc.	*Trans.*	III.	419	1893
Holgate, B.	Glacial Deposits in Teesdale	Leeds Geol. Assoc.	"	VII.	23	1892
Holmes, T. V.	Notes on the Geology of Upminster and Hornchurch	Essex F. C.	*Essex Naturalist*	VI.	96	"
" "	Notes on the Geology of Walthamstow	" "	" "	"	97	"
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" "	Notes on the Geology of Ilford	" "	" "	"	47	"
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Horne, J.	The Geology of Nairnshire	Inverness Sci. Soc.	*Trans.*	III.	51	"
" "	The North-west Succession of Rocks	" "	"	"	91	"
" "	Earthquakes	" "	"	"	404	"
Hoskold, H. D.	Notes upon the Mines in the Argentine Republic, South America	N. Eng. Inst.	"	3	617	1892
Howard, F. T.	A Note on Early Fossil Mammalia	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	12	1893
Hull, Prof. E.	On the Earthquake Shocks of August 17, 1892, in the British Isles and Central France	Manch. Geol. Soc.	*Trans.*	XXII.	197	"
Jefferson, S.	Some Geological Questions chemically considered	Leeds Geol. Assoc.	"	VII.	50	1892

Jeffs, O. W.	In Memoriam: Alexander Norman Tate, F.I.C.	Yorks. Nat. Union	*The Naturalist*	For 1892	305	”
Jones, Prof. T. Rupert	Coal: its Nature, Origin, Position, and Extent, and its Range under the South of England	Herts N. H. Soc.	*Trans.*	VII.	89	1893
Kendall, J. D.	The Iron Ores of Spain	N. Eng. Inst.	”	3	604	1892
Kendall, P. S.	The supposed Glacial Submergence	Leeds Geol. Assoc.	”	VII.	43	”
Lane, E.	The Coal and Mineral Resources of Peru	Fed. Inst. Min. Eng.	”	3	750	”
Lapworth, Prof. C.	Geology of the Caradoc and its Neighbourhood	Woolhope N. F. C.	”	1886-1889	241	”
Livingston, C.	The Travelled Boulders of Lochaber	Inverness Sci. Soc.	”	III.	3	1893
Lomas, J.	Report on the Glacial Deposits between Dingle Point, Liverpool, and Hale Head	Liv'pool Geol. Soc.	*Proc.*	VI.	396	1892
” ”	Some Potholes near Dingle Point	” ”	”	”	416	”
” ”	Some Faults exposed in a Quarry near Thingwall Mill	” ”	”	”	441	”
McDakin, Capt.	Some Forms of Chalk Life	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	83	1893
” ”	Landslip near Folkestone	” ”	” ”	”	97	”
McLaren, R.	A Reverse Fault in Kiltongue Coal at Drumshangie Colliery	Glasgow Geol. Soc.	*Trans.*	IX.	390	”
McLennan, J. S.	The Geology of Kyle	” ”	”	”	264	”
Marshall, W. P.	The Ice Ages, Past and Future, and their Causes	Birm. N. H. M. Soc.	*Mid. Naturalist*	XV.	121	1892
Miller, H.	The Sutors of Cromarty	Inverness Sci. Soc.	*Trans.*	III.	131	1893
” ”	The Black Rock of Novar	” ”	”	”	308	”
Moiser, H. R.	In Memoriam: William Reed	Yorks. Nat. Union	*The Naturalist*	For 1892	235	1892
Murton, C. J.	Geology of the Coalfield of Northumberland and Durham	N. Eng. Inst.	*Trans.*	3	620	”
Neilson, J.	On the Modern Manufacture of Ancient (?) Flint Implements, including an Interview with an Irish Flint Jack	Glasgow Geol. Soc.	”	IX.	367	1893
” ”	A Visit to the Island of Little Cumbrae, with some Notes on its Minerals	” ”	”	”	373	”
Painter, W. H.	The Devonian Rocks of Ilfracombe and Barnstaple	Birm. N. H. M. Soc.	*Mid. Naturalist*	XVI.	84	”
Paul, J. D.	Boring at the South Knighton Co-operative Shoe Works	Leicester Lit. Phil. Soc.	*Trans.*	III.	105	”
Platt, S. S.	Some of the recent Results of the Investigations into Local Erratic Blocks	Rochdale Lit. Sci. Soc.	”	”	52	”
Praeger, R. Lloyd	On the Skull of an Irish Elk found at Belfast	Belfast Nat. F. C.	*Report and Proc.*	”	416	1892
Proctor, C.	The Atmosphere in Early Geological Epochs	Inverness Sci. Soc.	*Trans.*	”	415	1893
Reade, T. M.	The Rounding of Sandstone Grains as bearing on the Divisions of the Bunter	Liv'pool Geol. Soc.	*Proc.*	VI.	374	1892

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Redmayne, R. A. S.	The Geology and Coal Deposit of Natal	N. Eng. Inst.	*Trans.*	4	—	1893
Rickard, T. A.	Mount Morgan Mine	Cornw. Min. Assoc. Inst.	,,	III.	133	1892
Robertson, J. R. M.	The Coalfields South of Sydney, New South Wales	Fed. Inst. Min. Eng.	,,	4	83	1893
Roeder, C.	Notes on Marine Shells derived from the post-Pliocene Deposits of Manchester and District	Manch. Geol. Soc.	,,	XXI.	607	1892
,, ,,	List of Shells from the Lower Boulder Clay at Heaton Mersey, near Manchester	,, ,,	,,	XXII.	206	1893
Shaw, J. L.	The Hæmatite Ores of Cumberland	N. Eng. Inst.	,,	3	580	1892
Shore, T. W.	Hampshire Mudlands and other Alluviums	Hants F. C.	*Proc.*	II.	181	1893
Smith, John	Peculiar U-shaped Tubes in Sandstone near Crawfurdland Castle, and in Gowkha Quarry, near Kilwinning	Glasgow Geol. Soc.	*Trans.*	IX.	289	,,
Smith, J.	The Ardrossan Shell-mound, with an Account of its Excavation	,, ,,	,,	,,	355	,,
Spencer, J.	Glacial Boulders in Calderdale	Yorks. Nat. Union	*The Naturalist*	For 1893	75	,,
Stirrup, M.	Delegate's Report of British Association Meeting at Edinburgh	Manch. Geol. Soc.	*Trans.*	XXII.	59	1892
Storrie, J.	On some Methods of Photographing the Geological Features of the Neighbourhood	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	22	1893
Swanston, W.	A Fossiliferous Ironstone Nodule	Belfast Nat. F. C.	*Report and Proc.*	III.	401	1892
Symons, B.	The Goldfields of Nova Scotia	Cornw. Min. Assoc. Inst.	*Trans.*	,,	80	,,
Tate, T.	How to recognise Lake Country Rocks	Leeds Geol. Assoc.	,,	VII.	18	,,
,, ,,	The Yorkshire Boulder Committee and its Fifth Year's Work	Yorks. Nat. Union	*The Naturalist*	For 1892	161	,,
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,, ,,	The Yorkshire Boulder Committee and its Sixth Year's Work	,, ,,	,, ,,	For 1893	109	1893
Thompson, B.	Report of the British Association Committee appointed to work the Transition Beds of the Northamptonshire Lias	N'ton. N. H. Soc.	*Journal*	VII.	35	1892
Ussher, W. A. E.	The British Culm Measures	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVIII.	111	,,
Walker, J. F.	On the Brachiopoda recently discovered in the Yorkshire Oolites	Yorks. Phil. Soc.	*Report*	For 1892	47	1893

		Inverness Sci. Soc.	Trans.	III.	134	,,
Wild, G.	The Method and Value of Fossil Collection in Coal Mining	Manch. Geol. Soc.	,,	XXII.	222	,,
Wilson, Rev. A. S.	Notes on the Geology of Fife	Glasgow Geol. Soc.	,,	IX.	392	,,
Wilson, T. H.	Notes on the Gravel in Epping Forest	Essex F. C.	*Essex Naturalist*	VII.	74	,,
Winwood, Rev. H. H.	Notes on some Deep Well Borings in Somersetshire	Bath N. H. A. F. C.	*Proc.*	,,	335	,,
Woodward, H. B.	Notes on the Geology of Crewkerne	Som'setsh. A. N. H. Soc.	,,	XXXVII.	60	1892
Worth, R. N.	The Age and History of the Granites of Devon and Cornwall	Cornw. R. Geol. Soc.	*Report and Trans.*	XI.	480	1893
Young, J.	Note on the Group of Carboniferous Ostracoda found in the Strata of Western Scotland, with a revised List of Genera and Species	Glasgow Geol. Soc.	*Trans.*	IX.	301	,,
,, ,,	Notes on a small Group of Carboniferous Foraminifera found in the Lower Limestone Shales of the Muirkirk District in Ayrshire, with a List of the Genera and Species found in the Coalfields of Western Scotland	,, ,,	,,	,,	313	,,
Young, Prof. J.	Memoir of the late Sir Andrew Ramsay, F.R.S.	Glasgow Phil. Soc.	*Proc.*	XXIII.	281	1892
Zeiller, R.	On the Fossil Plants of the Dover Coal	Manch. Geol. Soc.	*Trans.*	XXII.	55	,,

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Aitken, Dr.	The Beaver	Inverness Sci. Soc.	*Trans.*	III.	196	1893
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Armistead, J. J.	Improvement of our Freshwater Fisheries	Dum. Gal. N. H. A. Soc.	,,	No. 8	13	,,
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Armstrong, J. N.	Presidential Address: Tennyson as a Naturalist	Rochester N. C.	*Roch. Naturalist*	II.	101	1892
Bainbridge, F.	The Great Cowthorpe Oak Tree	Woolhope N. F. C.	*Trans.*	1886–89	340	,,
Baker, J. G.	North Yorkshire: Studies of its Botany, Geology, Climate, and Physical Geography	Yorks. Nat. Union	,,	3	337	,,
Barclay, W.	Flora of the Left Bank of the Tay between Perth and Glencarse	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	245	,,
Barke, F.	Geological Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	108	,,
,, ,,	Gypsum Mines at Fauld	,, ,,	,, ,,	,,	112	,,
Barnes, R.	*Distichium inclinatum*, an Addition to the Moss Flora of England	Yorks. Nat. Union	*The Naturalist*	For 1892	186	,,
Batten, E. C.	The Forest Trees of Somerset	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVII.	106	,,

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Bennett, A.	Notes on some Scotch Plants, especially with relation to Dumfriesshire and Galloway, and their relation as Native Species	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	85	1893
" "	A Botanical Run through the Fens	Holmesdale N. H. C.	*Proc.*	For1890-92	78	"
Blaber, W. H.	British Lepidoptera: their Metamorphoses, Structure, and Habits	" "	"	"	39	"
Bolam, G.	Daubenton's Bat in Northumberland and on the Borders; with some Remarks upon the other Species recorded for the District	Yorks. Nat. Union	*The Naturalist*	For 1892	269	1892
" "	Note on 'The supposed Inter-breeding of the Merlin and Kestrel in Northumberland in 1886'	" "	" "	"	369	"
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Boyd, D. A.	Notes on the Occurrence of *Helotium marchantiæ*, Berk., in Ayrshire	Glasgow N. H. Soc.	*Proc. and Trans.*	III.	272	"
Buckley, T. E.	A few Notes on the Migratory Habits of the Red Grouse (*Lagopus Scoticus*)	Inverness Sci. Soc.	*Trans.*	III.	441	1893
Bucknall, C.	List of Fungi found in the Forest of Dean	Woolhope N. F. C.	"	1886–89	193, 272	1892
Buttress, L.	Ornithological Notes from North Notts for 1891–2	Yorks. Nat. Union	*The Naturalist*	For 1893	87	1893
Cambridge, Rev. O. P.	On the British Species of False Scorpions	Dorset N. H. A. F. C.	*Proc.*	XIII.	199	1892
Chapman, Dr. T. A.	Notes on the Flight of *Hepialus humuli*	Woolhope N. F. C.	*Trans.*	1886–89	87	"
" "	The Life History of *Anthocaris cardamines*	" "	"	"	101	"
" "	The Leafing of the Oak Tree and of the Ash Tree	" "	"	"	341	"
Clarke, H. S.	Entomological Report, 1891–92	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	II.	378	"
" "	The Heterocera of the Isle of Man	" "	" "	"	387	"
Cleland, Prof. J.	How our Bones grow	Glasgow Phil. Soc.	*Proc.*	XXIII.	55	"
Cole, W.	The 'Holy Thorn' at Woodham Ferrers, Essex	Essex F. C.	*Essex Naturalist*	VII.	48	1893
Cooke, Dr. M. C.	Notes and Queries on *Russulæ*	Woolhope N. F. C.	*Trans.*	1886–89	274	1892
Corbett, H. H.	*Lithocolletis cerasicolella*: a Species new to the British Fauna at Doncaster	Yorks. Nat. Union	*The Naturalist*	For 1893	112	1893

Cordeaux, J.	Occurrence of the common Rorqual, or Finner, in the Humber	,, ,,	,, ,,	For 1892	187	1892
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Creaghe-Haward, L.	Notes on some East Anglian Birds	Leicester Lit. Phil. Soc.	,,	II.	538	1892
Crellin, J. C.	Zoological Report, 1891–92	I. of Man N. H. A. Soc.	*Yn Lioar Manninagh*	II.	377	,,
Crosfield, A. J.	Mid-winter in Corsica	Holmesdale N. H. C.	*Proc.*	For 1890–92	48	1893
Crosfield, J. B.	Nesting of the Kentish Plover	,, ,,	,,	,,	3	,,
Crossland, C.	New West Yorkshire Fungi, and additional Localities for others previously recorded	Yorks. Nat. Union	*The Naturalist*	For 1892	261	1892
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Crouch, W.	Further Notes on the Burnham Rorqual (*Balænoptera musculus*)	Essex F. C.	*Essex Naturalist*	VII.	50	1893
Cunningham, J. T.	The Preservation of Marine Animals for Zoological Purposes	,, ,,	,, ,,	,,	118	1892
Daltry, Rev. T. W.	Entomological Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	74	,,
Dixon, H. N.	Notes on Northamptonshire Plants	N'ton. N. H. Soc.	*Journal*	VII.	95	,,
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Docharty, W.	Marine Zoology	Inverness Sci. Soc.	*Trans.*	III.	57	1893
Druce, G. C.	The Flora of Northamptonshire	N'ton. N. H. Soc.	*Journal*	VII.	64, 136	1892
Duckworth, T.	Reminiscences in the Study of Natural History	Cumb. West Assoc.	*Trans.*	XVII.	91	,,
Duncan, Dr. E.	On the Causes of the Spread of Pulmonary Consumption and other Tubercular Diseases	Glasgow Phil. Soc.	*Proc.*	XXIII.	237	,,
Edwards, W.	Notes on the Entomology of Northamptonshire	N'ton. N. H. Soc.	*Journal*	VII.	19	,,
Elliott, G. F. S.	New and rare Botanical Finds in 1891	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	11	1893
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Field, Rev. T.	Analogies of Sociology and Biology	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	78	1893
Fowler, W. W.	Notes on Wagtails	Woolhope N. F. C.	*Trans.*	1886–89	145	1892
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Fraser, Rev. Mr.	The Botany of Croy	Inverness Sci. Soc.	"	III.	38	1893
French, J.	Some Minor Problems concerned in the Local Distribution of Animals and Plants in the Neighbourhood of Felstead, Essex	Essex F. C.	*Essex Naturalist*	VI.	191	1892
Friend, Rev. H.	A new Yorkshire Earthworm	Yorks. Nat. Union	*The Naturalist*	For 1892	247	"
" "	On Hybridity among Worms	" "	" "	"	301	"
" "	A Check-list of British Earthworms	" "	" "	For 1893	17	1893
" "	New British Worms	" "	" "	"	55	"
" "	British Annelids, with especial reference to the Earthworms of Essex	Essex F. C.	*Essex Naturalist*	VI.	107, 169 185	1892
Gossip, J. A.	Poisonous Plants and Vegetable Poisons	Inverness Sci. Soc.	*Trans.*	III.	263	1893
Gould, T. C.	A Naturalist in Essex a century and a half ago	Essex F. C.	*Essex Naturalist*	VI.	112	1892
Grant, Dr. O.	Highland Ornithology	Inverness Sci. Soc.	*Trans.*	III.	310	1893
Guthrie, Prof.	On the Subjective Causes of Evolution as illustrated by the Geographical Distribution of Plants	S. African Phil. Soc.	"	V.	275	"
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Heathcote, Rev. E. D.	Notes on some Hampshire Mosses	Hants F. C.	*Proc.*	II.	217	"
Hey, Rev. W. C.	A real Summer's Day	Yorks. Nat. Union	*The Naturalist*	For 1892	292	1892
Hill, A. W.	Notes on the Differences between *Habenaria chlorantha* and *H. bifolia* (the Greater and Lesser Butterfly Orchis)	Marlb. Coll. N. H. Soc.	*Report*	41	102	1893
Hilliar, J.	An Angler's Notes on Dagenham Lake	Essex F. C.	*Essex Naturalist*	VI.	146	1892
Hinxman, L. W.	The Breeding of the Snow Bunting in Assynt	Inverness Sci. Soc.	*Trans.*	III.	195	1893
Hopkinson, J.	Anniversary Address: Charles Darwin	Herts N. H. Soc.	"	VII.	101	"
Hottinger, Miss	Notes on the Alpine Flora	Leicester Lit. Phil. Soc.	"	III.	107	"
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Johnson, Rev. W. F.	The Beetles of the Belfast District	Belfast Nat. F. C.	*Report and Proc.*	III.	402	,,
Johnstone, J. T.	Notes on the Flora of the Moffat District for 1891	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	18	1893
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Kew, H. W.	The Faculty of Food-finding in Gastropods	Yorks. Nat. Union	*The Naturalist*	For 1893	145	1893
Kidston, R.	The Yorkshire Carboniferous Flora	,, ,,	*Trans.*	Part 18	65	,,
Laver, Dr. H.	Periodicity in Organic Life	Essex F. C.	*Essex Naturalist*	VII.	51	,,
Lewis, H.	Notes on Birds observed in Hertfordshire during the year 1891	Herts N. H. Soc.	*Trans.*	,,	62	1892
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Lister, A.	Mycetozoa	Dorset N. H. A. F. C.	*Proc.*	XIII.	130	,,
M'Andrew, J.	A Contribution to the Cryptogamic Botany of the Moffat District	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	30	1893
,, ,,	Botanical Notes from Wigtownshire, Kirkcudbrightshire, and Dumfriesshire in 1890	Glasgow N. H. Soc.	*Proc. and Trans.*	III.	260	1892
MacCormac, Dr. J.	The Influence of Language and Environment upon the Individual through the Nervous System	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	93	1893
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Marloth, Dr. R.	The 'Naras' *Acanthosicyos Horrida*, Hook	S. African Phil. Soc.	*Trans.*	V.	229	1893
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Martin, Miss	A Month in the Canaries	Holmesdale N. H. C.	*Proc.*	For 1890-92	88	,,
Masefield, J. R. B.	Zoological Report	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	54	1892
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Meldrum, R. H.	*Hypnum procerrimum*, Molendo; a new British Moss	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	255	1892
Meyrick, E.	Hand-list of Lepidoptera of the District	Marlb. Coll. N. H. Soc.	*Report*	41	72	1893
" "	Notes on Lepidoptera	" "	"	"	122	"
Montgomerie, Dr. H.	The Torpedo Ray	Penz. N. H. A. Soc.	*Report and Trans.*	IV.	52	"
" "	Oysters	" "	" "	"	65	"
Moore, H. C.	The Great Oak Tree at Newland	Woolhope N. F. C.	*Trans.*	1886–1889	339	1892
Mosley, S. L.	Yorkshire Galls	Yorks. Nat. Union	*The Naturalist*	For 1892	273	"
" "	Additional Yorkshire Galls	" "	" "	"	337	"
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" "	A Study of the Botanical Order *Ranunculaceæ*	" "	"	III.	7	"
Murray, Dr.	A Visit to M. Pasteur's Laboratory	Inverness, Sci. Soc.	"	"	205	1893
Nelson, T. H., and W. E. Clarke	Scorpæna *dactyloptera* on the Yorkshire Coast: An Addition to the Fauna of the British North Sea Area	Yorks. Nat. Union	*The Naturalist*	For 1893	81	"
Norman, Rev. Canon A. M.	Rare Crustacea on the Yorkshire Coast	" "	" "	For 1892	175	1892
Painter, Rev. W. H.	Botany as a Science and Recreation, with Notes upon the Plants in Biddulph, &c.	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	95	"
Péringuey, L.	Descriptive Catalogue of the Coleoptera of South Africa: Cicindelidæ	S. African Phil. Soc.	*Trans.*	VII.	1	1893
Petty, L.	The Plants of Leck and Neighbourhood, Lancashire	Yorks. Nat. Union	*The Naturalist*	For 1893	91	"
" "	A few Plants of South-west Cumberland	" "	" "	"	139	"
Phillips, E. C.	A Visit to the Bird Rock (Craig-y-Deryn), Towyn, North Wales	Woolhope N. F. C.	*Trans.*	1886-1889	283	1892
" "	A Plea for the Owl	" "	"	"	285	"
" "	The Great Black Woodpecker in England	" "	"	"	392	"
Phillips, W.	Methods of Reproduction in Fungi	" "	"	"	189	"
Pound, C. J.	Bacteria: their Structure and Cultivation	S. London M. N. H. C.	*Report*	21st	7	"
Price, J. H.	The rarer Hawks of Breconshire	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	31	1893
Quail, A.	Lepidoptera from the Neighbourhood of Northampton	N'ton. N. H. Soc.	*Journal*	VII.	115	1892

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Rendle, A. B.	Leaves: their Forms and Uses	S. London M. N. H. C.	*Report*	21st	10	"
Richardson, N. M.	Notes on Dorset Lepidoptera in 1891	Dorset N. H. A. F. C.	*Proc.*	XIII.	168	"
Roberts, T. V.	Terrestrial British Quadrupeds existing in a Wild State at the present day	Herts N. H. Soc.	*Trans.*	VII.	41	"
Robertson, D.	*Phycis blennoides* (Brün)	Glasgow N. H. Soc.	*Proc. and Trans.*	III.	267	"
" "	*Zeugopterus punctatus*, Bl.	" "	" "	"	"	"
" "	*Pleurobranchus plumula*, Mont.	" "	" "	"	268	"
" "	*Uraster glacialis*, L.	" "	" "	"	269	"
" "	*Ascophyllum Mackaii* forma Robertsoni, Batt.	" "	" "	"	70	"
Robinson, Dr. H. B.	Presidential Address: Parasites	S. London M. N. H. C.	*Report*	21st	212	"
Roebuck, W. D.	Bibliography: Birds, 1889	Yorks. Nat. Union	*The Naturalist*	For 1892	281	"
" "	The Yorkshire Naturalists' Union at Withernsea	" "	" "	"	293	"
" "	Bibliography: Land and Freshwater Mollusca, 1888 and 1889	" "	" "	"	327	"
" "	" Diptera, 1888, 1889, 1890, and 1891	" "	" "	For 1893	21	1893
" "	" Mammalia, 1889–91	" "	" "	"	59	"
" "	" Birds, 1890	" "	" "	"	115	"
Rooper, G.	Bats and some other Beasts	Herts N. H. Soc.	*Trans.*	VII.	37	1892
Rowley, F. R.	Note on the Collection of Micro-organisms contained in the University Museum, Oxford	Leicester Lit. Phil. Soc.	"	III.	102	1893
Salmon, C. E.	Nesting of the Norfolk Plover	Holmesdale N. H. C.	*Proc.*	For1890–92	66	"
" "	Short Botanical Rambles	" "	"	"	96	"
" "	A Summer Holiday in Cornwall and the Scilly Isles	" "	"	"	35	"
" "	Three Weeks' Holiday in North Wales in pursuit of Natural History	" "	"	"	57	"
Salmon, E. S., and A. J. Crosfield	A Week in Teesdale	" "	"	"	99	"
Scobie, A.	On the Nesting Habits of the Kingfisher (*Alcedo ispida*, L.)	Glasgow N. H. Soc.	*Proc. and Trans.*	II.	255	1892
Scott, A.	Notes on *Cecrops Latreillii*, Leach, and *Læmargus muricatus*, Kroyer	" "	" "	"	266	"
Scott, T.	Notes on *Rhincalanusgigas*, Brady, and *Ectinosoma atlanticum*, Brady and Robertson	" "	" "	"	—	—
Seeley, Prof. H. G.	On *Omosaurus Phillipsi* (Seeley)	Yorks. Phil. Soc.	*Report*	For 1892	52	1893
Sharp, W. E.	Heredity and Variation	Liv'pool Lit. Phil. Soc.	*Proc.*	XLVI.	59	1892

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Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Sharp, W. E.	The Hydraphega of Lancashire and Cheshire	Yorks. Nat. Union	*The Naturalist*	For 1892	189	1892
Smith, Capt. T. J.	Remarks on *Apis Mellifica*, the Hive Bee	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	52	,,
Smithson, T. S.	Bead Moss	Rochdale Lit. Sci. Soc.	*Trans.*	III.	1	1893
Stewart, Prof. C.	Some Peculiar Forms of Life	S. London M. N. H. C.	*Report*	21st	6	1892
Stuart, M. G.	Observations on the Flowering of Plants and Appearances of Birds and Insects in Dorset during 1891	Dorset N. H. A. F. C.	*Proc.*	XIII.	239	,,
Sutherland, Dr.	The St. Kilda Flora	Inverness Sci. Soc.	*Trans.*	III.	218	1893
,, ,,	Insects and Plants	,, ,,	,,	,,	221	,,
Sykes, E. R.	On some Monstrosities of *Littorina rudis*, Maton	Dorset N. H. A. F. C.	*Proc.*	XIII.	191	1892
Tinkler, J. E.	Notes on the Avi-Fauna of Arkengarthdale, Swaledale, and the New Forest	Yorks. Nat. Union	*The Naturalist*	For 1892	309	,,
Trail, Prof.	Additions to the Flora of Scotland	Inverness Sci. Soc.	*Trans.*	III.	408	1893
Trew, A. H.	Notes on the Flora of the Society's District	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	13	,,
Trimen, R.	Note on the Teeth of the Ziphioid Whale	S. African Phil. Soc.	*Trans.*	V.	295	,,
Tuck, Rev. J. G.	The Ornithology of Tennyson	Yorks. Nat. Union	*The Naturalist*	For 1893	41	,,
Various	Phenological Records for 1891	Bristol Nat. Soc.	*Proc.*	VII.	4	1892
Vize, Rev. J. E.	Land and Freshwater Shells	Woolhope N. F. C.	*Trans.*	1886–1889	180	,,
,, ,,	Spiders, British and Foreign	,, ,,	,,	,,	291	,,
Waddell, Rev. C. H.	The late Mr. John Templeton's Work among the Birds of the District	Belfast Nat. F. C.	*Report and Proc.*	III.	409	,,
Waite, E. R.	Remains of Fallow Deer from Goole Moor	Yorks. Nat. Union	*The Naturalist*	For 1892	167	,,
,, ,,	The Yorkshire Naturalists' Union at Horton in Ribblesdale	,, ,,	,, ,,	,,	177	,,
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,, ,,	The Yorkshire Naturalists' Union at Coxwold and Byland	,, ,,	,, ,,	,,	343	,,
Wardle, T.	The Entomology and Uses of Silk	N. Staff. N. F. C. A. Soc.	*Report and Trans.*	XXVI.	16	,,
Watkins, Rev. M. G.	The Migration of Birds	Woolhope N. F. C.	*Trans.*	1886–1889	262	,,

[illegible]	The Climatic Change now commenced in Great Britain, and its probable Influences on our future Fauna and Flora	E. Kent N. H. Soc.	*S.E. Naturalist*	I.	86	1893
„	Hibernation and Hibernating Creatures	„ „	„ „	„	93	„
Wensley, Rev. E. B.	What Sense in Insects supplies the place of Sight	Rochester N. C.	*Roch. Naturalist*	II.	157	„
West, W.	The Evolution of Animals	S. London M. N. H. Club	*Report*	21st	„	1892
Wharton, H. T.	On Dr. Bull's 'Notes on the Birds of Herefordshire'	Woolhope N. F. C.	*Trans.*	1886–1889	287	„
White, Dr. F. B.	Opening Address	Perths. Soc. N. Sci.	*Trans. and Proc.*	I.	cxxiii	„
„ „	Retiring Address	„ „	„ „	„	cxxxv	„
Whitlock, F. B.	The supposed inter-Breeding of the Merlin and Kestrel in Northumberland in 1886	Yorks. Nat. Union	*The Naturalist*	For 1892	341	„
„ „	Northumberland Bird Notes	„ „	„ „	For 1893	83	1893
„ „	Bird Notes from Nottinghamshire, 1892–3	„ „	„ „	„	85	
Whitwell, W.	West Yorkshire Records and Notes from the Herbarium, Catalogues, &c., of the late Mr John Tatham, of Settle	„ „	„ „	„	25	„
Willis, J. J.	A Naturalist's Calendar for Mid-Hertfordshire	Herts N. H. Soc.	*Trans.*	VII.	76	„
Wotton, F. W.	The Life History of *Arion Atex*	Cardiff Nat. Soc.	*Report and Trans.*	XXIV.	25	„
Yates, J.	Botanical Report	N. Staff. N. F. C. A. Soc.	„ „	XXVI.	92	1892

Section E.—GEOGRAPHY.

Allen, Prof. F. J.	A Photographic Survey of Somerset	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVII.	100	1892
Bent, J. T.	The Geography of the Zimbabwe Ruins in Mashonaland	Manch. Geog. Soc.	*Journal*	VII.	295	„
Brower, J. V.	The Source of the Mississippi River	„ „	„	„	301	„
Buchanan, J.	The Industrial Development of Nyasaland	Tyneside Geog. Soc.	„	II.	137	1893
Casartelli, Rev. L. C.	Report on Examination on India, 1892	Manch. Geog. Soc.	„	VIII.	76	„
Chinnock, Dr. E. J.	Captain Franck's Tour in Scotland in 1657	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	22	„
Cole, Rev. E. M.	The Physical Geography of Central Africa	Leeds Geol. Soc.	„	VII.	26	1892
Crook, H. T.	The Ordnance Maps: the Defects and their Remedies	Fed. Inst. Min. Eng.	„	4	12	1893
Crouch, W.	Dagenham Breach	Essex F. C.	*Essex Naturalist*	VI.	155	1892
De Winton, Gen. Sir F.	Canada and the Great North-West	Manch. Geog. Soc.	*Journal*	VIII.	83	1893
Dobson, G.	The River Volta, Gold Coast, West Africa	„ „	„	„	19	„

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Editor, The	Dr. Nansen and the North Pole	Manch. Geog. Soc.	*Journal*	VII.	339	1892
Froehlich, Chev.	Columbus and Genoa	,, ,,	,,	VIII.	137	1893
Ganzenmüller, Dr. K.	Instructions for Correct Pronunciation of Foreign Geographical Names	,, ,,	,,	VII.	332	1892
Gray, P.	Scotland in the Past	Dum. Gal. N. H. A. Soc.	*Trans.*	No. 8	57	1893
Guillaume, Chev.	The Basin of the Beni	Manch. Geog. Soc.	*Journal*	VII.	342	1892
,, ,,	A Journey to the Gold Regions of Sandia and Carabaya, Southern Peru	,, ,,	,,	VIII.	193	1893
Heywood, A., jun.	Travel in Western Norway	,, ,,	,,	,,	178	,,
Jephson, Capt. A. J. M.	Trade Prospects in Uganda and East Central Africa	,, ,,	,,	,,	65	,,
Jones, H.	Russia of To-day	Tyneside Geog. Soc.	,,	II.	135	,,
King, F. D.	New Map for Teaching Local Geography: Description of a Contour Map of Yorkshire	Manch. Geog. Soc.	,,	VII.	326	1892
Klein, Rev. L. E. B.	Scientific Hints to Missionaries	,, ,,	,,	VIII.	206	1893
Lancaster, W., jun.	An Ascent of the Matterhorn	,, ,,	,,	,,	191	,,
Lugard, Capt. F. D.	Uganda: its Value to British Trade	,, ,,	,,	,,	101	,,
Meakin, J. B.	Morocco: as it is and might be	,, ,,	,,	,,	55	,,
Merivale, Prof. J. H.	The Ordnance Maps	N. Eng. Inst.	*Trans.*	3	903	1892
Morgan, E. D.	Antarctic Explorations	Manch. Geog. Soc.	*Journal*	VII.	311	,,
Morris, Gwyn	The Teaching of Commercial Geography	,, ,,	,,	,,	328	,,
Nansen, Dr. F.	The North Pole	,, ,,	,,	VIII.	61	1893
Ravenstein, E. G.	The Field of Geography	,, ,,	,,	VII.	313	1892
Reed, J. H.	The Congo: its Discovery and Exploration	,, ,,	,,	VIII.	26	1893
Ross, A.	A Visit to the Island of St. Kilda	Inverness Sci. Soc.	*Trans.*	III.	72	,,
Sowerbutts, E.	The British Association at Edinburgh, 1892	Manch. Geog. Soc.	*Journal*	VIII.	174	,,
Steinthal, Rev. S. A.	Columbus	,, ,,	,,	,,	129	,,
Steinthal, W. M.	A Peep at the Land of the Rising Sun	,, ,,	,,	VII.	277	1892
Thomson, J. P.	Ascent of Mount Yule	,, ,,	,,	,,	294	,,
,, ,,	Exploration and Discoveries in British New Guinea since the Proclamation of Sovereignty	,, ,,	,,	VIII.	42	1893
,, ,,	Practical Suggestions to Travellers	Tyneside Geog. Soc.	,,	II.	113	,,
Vambéry, Prof. A.	The Turco-Tartars	Manch Geog. Soc.	,,	VIII.	1	,,
Wallace, T.	Notes on the Parish of Kirkhill	Inverness Sci. Soc.	*Trans.*	III.	114	,,
Waller, W. C.	The Old Track from London to Epping	Essex F. C.	*Essex Naturalist*	VI.	206	1892

Col. C. M. .		... Geog. Soc.	Journal	II.	150	1893
Wilkinson, W. N.	A Trip to Egypt	Birm. N. H. M. Soc.	*Mid. Naturalist*	XVI.	73	"
Wylde, A. B.	Suakin and District	Manch. Geog. Soc.	*Journal*	VIII.	185	"

Section F.—ECONOMIC SCIENCE AND STATISTICS.

Barratt, Rosa M.	Legislation on Behalf of Neglected Children in America and elsewhere	Stat. Soc. Ireland	*Journal*	9	616	1892
Benas, B. L.	The Philosophy of the Labour Question	Liv'pool Lit. Phil. Soc.	*Proc.*	XLVI.	1	"
Bourne, S.	The Extent of Food Imports into the United Kingdom	Manch. Stat. Soc.	*Trans.*	For 1892-93	25	1893
Callie, J. W. S.	The Labour Problem	Liv'pool Lit. Phil. Soc.	*Proc.*	XLVI.	147	1892
Casartelli, Dr. L. C.	Eastward Ho! Some Considerations on our Responsibilities in the East	Manch. Stat. Soc.	*Trans.*	For 1892-93	77	1893
Collins, J. H.	Seven Centuries of Tin Production in the West of England	Cornw. Min. Assoc. Inst.	"	III.	173	1892
Colville, Dr. J.	The Rural Economy of Scotland in the Time of Burns	Glasgow Phil. Soc.	*Proc.*	XXIII.	120	"
Findlater, W.	Presidential Address: The History and Method of Statistics	Stat. Soc. Ireland	*Journal*	9	636	"
Fogg, W.	Workers in Cotton Factories and the Eight Hours Day	Manch. Stat. Soc.	*Trans.*	For 1892-93	1	1893
Finlay, Rev. T. A.	Co-operative Agricultural Societies in Germany	Stat. Soc. Ireland	*Journal*	9	605	1892
Gray, W.	The Essentials of House Sanitation—How to Secure them	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	111	1893
Hollowell, Rev. J. H.	A Statistical View of the Anomalies of our Educational System	Manch. Stat. Soc.	*Trans.*	For 1892-93	61	"
Hoskold, H. D.	Notes upon Redemption of Capital invested in Collieries	Fed. Inst. Min. Eng.	"	3	735	1892
Hughes, W. R.	Herbert Spencer's 'Principles of Ethics'	Birm. N. H. M. Soc.	*Mid. Naturalist*	XVI.	108	1893
Humphreys-Davies, G.	Colliery Assessments and the Rating of Mining Machinery	Fed. Inst. Min. Eng.	*Trans.*	3	773	1892
Lawson, Dr. W.	The Fusion of the Two Branches of the Legal Profession	Stat. Soc. Ireland	*Journal*	9	632	"
Mackay, W.	Prison Life in Inverness between 1700 and 1720	Inverness Sci. Soc.	"	III.	98	1893
McMaster, J. M.	On Plans for Regulating the Paper Currency	Liv'pool Lit. Phil. Soc.	*Proc.*	XLVI.	231	1892

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M'Math, W.	Progress of School Building in Glasgow	Glasgow Phil. Soc.	*Proc.*	XXIII.	106	1892
Murphy, J. J.	A Suggestion for the Fusion of the Two Branches of the Legal Profession	Stat. Soc. Ireland	*Journal*	9	613	"
Rylett, Rev. H.	The Effect of the Taxation of Land Values on Local Rates	Manch. Stat. Soc.	*Trans.*	For1892-93	49	1893
Smart, W.	Women's Wages	Glasgow Phil. Soc.	*Proc.*	XXIII.	87	1892
Sowerbutts, E.	Considerations in relation to State Insurance of Old Age Pensions and other Benefits	Manch. Stat. Soc.	*Trans.*	For1892-93	101	1893
Stirrup, M.	On some recent Estimates of the World's Coal Supply	Manch. Geol. Soc.	"	XXII.	227	"
Stuart, T. W.	The Tees Salt Industry	N. Eng. Inst.	"	3	632	1892
Symons, B. (translated by)	A History of Tin	Cornw. Min. Assoc. Inst.	"	IV.	138	1893
Veitch, R.	Our Local Problem of Poverty	Rochdale Lit. Sci. Soc.	"	III.	21	"
Watson, W.	The A, B, C of Hygiène	Rochester N. C.	*Roch. Naturalist*	II.	137	"
Wilkinson, W. F.	Miners' Insurance Funds in England and Germany	Cornw. Min. Assoc. Inst.	*Trans.*	IV.	81	"

Section G.—MECHANICAL SCIENCE.

Name of Author	Title of Paper	Abbreviated Title of Society	Title of Publication	Volume or Part	Page	Published
Aitken, W.	On Telephone Switch-boards, being principally a Description of the new Telephone Exchange, Glasgow	Glasgow Phil. Soc.	*Proc.*	XXIII.	185	1892
Barling, T. C.	Sounding Apparatus	Liv'pool E. Soc.	*Trans.*	XIII.	29	"
Bassett, W. B.	The Extraction of Magnetic Particles from Auriferous and other Ores	Fed. Inst. Min. Eng.	"	4	53	1893
Binns, G. J	An improved Head Gear for Pit Horses	Chesterf. Mid. Count. Inst.	"	4	427	"
" "	Mining in New Zealand:					
	Part 1. Gold Mining	Fed. Inst. Min. Eng.	"	3	644	1892
	Part 2. Miscellaneous Mining	" "	"	4	59	"
Brier, H.	Manufacture of Oxygen by Brins' Process, Compressing Gases in Cylinders, &c.	Glasgow Phil. Soc.	*Proc.*	XXIII.	212	"
Brightmore, A. W.	Methods of Collecting Water for Supply	Liv'pool E. Soc.	*Trans.*	XIII.	42	1892
Brough, B. H.	Use of Cement in Shaft Sinking	N. Eng. Inst.	"	4	343	1893

Capell, Rev. G. M.	Observations on Fans of different Types working in the same Upcast Shaft	" "	"	"	203	1892
Charleton, A. G.	The Choice of Coarse and Fine Crushing Machinery and Processes of Ore Treatment: Part 1	" "	"	"	233	"
	Part 2	" "	"	"	351	1893
Charleton, R. J.	A Safety Appliance for preventing Risk of Explosions in Mines consequent on Injury to Cables conveying Electric Currents	" "	"	3	570	1892
Clowes, Prof. F.	A Portable Safety Lamp with Ordinary Oil illuminating Flame, and Standard Hydrogen Flame for accurate and delicate testing	Fed. Inst. Min. Eng.	"	4	441	1893
Craig, E.	The Opening-out and Working of the Rearer Coals of North Staffordshire	" "	"	"	48	"
Davies, M. W.	Winding by Water Balance at Ynis Merthyr Colliery	" "	"	3	746	1892
Dixon, J. H.	Old Iron Works in Gairloch	Inverness Sci. Soc.	"	III.	6	1893
Donkin, B., jun.	Steam Boilers with Forced Blast: The Perrit System for Burning Dust and rejected Fuels; with Notes on Testing Boilers	N. Eng. Inst.	"	4	154	1892
Eastlake, A. W.	Observations on Petroleum in Eastern Europe, and the Method of Drilling for it	Fed. Inst. Min. Eng.	"	3	693	"
Fitzgerald, Prof. M. F.	The Contrast of Theory and Practice	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	21	1893
Fryer, Dr. A. C.	Some Notes on Ancient Mortars	Bristol Nat. Soc.	*Proc.*	VII.	36	1892
Garnett, Prof. W.	The Electric Transmission of Power and its Analogies in Hydraulics	N. Eng. Inst.	*Trans.*	3	914	"
Harvey, H. N.	Cornish Boilers	Cornw. Min. Assoc. Inst.	"	IV.	17	1893
Harvey, J. W. I.	Mild Steel	Bristol Nat. Soc.	*Proc.*	VII.	46	1892
Hambly, W.	The Diamond Mines of South Africa	Cornw. Min. Assoc. Inst.	*Trans.*	III.	14	"
Hall, H.	On Mis-shots in Mines	Manch. Geol. Soc.	"	XXII.	151	1893
Hendy, J. C. B.	Experiments upon a Waddell and a Capell Fan working on the same Mine at equal Periphery Speeds at Taversal Colliery	Fed. Inst. Min. Eng.	"	4	474	"
Hicks, J.	The Treatment of Slime Tin	Cornw. Min. Assoc. Inst.	"	IV.	123	"
Hopton, W.	On a new Design of Ventilating Fan for Collieries	Manch. Geol. Soc.	"	XXI.	582	1892
Johnson, I.	On the Substitution of Steel and Iron for Timber in Mines	" "	"	XXII.	145	1893

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Lanyon, J.	The proposed Belfast Central Station and Railways	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	40	1893
Little, G. H.	Transport of Petroleum in Bulk in Tropical Waters	Liv'pool E. Soc.	*Trans.*	XIII.	102	1892
Macadam, W. I.	Notes on the Ancient Iron Industry of Scotland	Inverness Sci. Soc.	,,	III.	222	1893
M'Ara, A.	On Limes and Cements	Glasgow Phil. Soc.	*Proc.*	XXIII.	24	1892
Macassey, L. L.	The Filtration Works for the Improvement of the Water Supply of Belfast	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	56	1893
Mac Ilwaine, J. H.	The Tonnage of Ships	,, ,,	,, ,,	,,	155	,,
Macnellan, J. E.	On Van Wyk's Vley Reservoir	S. African Phil. Soc.	*Trans.*	V.	219	,,
Maginnis, A. J.	Transatlantic Lines and Steamships: Part II.	Liv'pool E. Soc.	,,	XIII.	56	1892
Manners, C. R.	A Short History of Bridge Building	Inverness Sci. Soc.	,,	III.	321	1893
Marsh, F. S.	One Use for the Telephone	Chesterf. Mid. Count. Inst.	,,	3	1007	1892
Moore, R. T.	The Mineral Oil Industry of Scotland	Fed. Inst. Min. Eng.	,,	4	36	1893
,, ,,	Joseph Moore's Hydraulic Pumping Arrangement	N. Eng. Inst.	,,	,,	331	,,
Morris, T.	Engineers' Tests for Iron considered; and Suggestions for Standard Uniform Tests	Liv'pool E. Soc.	,,	XIII.	70	1892
Mortimer, J.	How a Lace Curtain is made	Manch. Geog. Soc.	*Journal*	VIII.	115	1893
Phillips, W. G.	Underground Haulage by Endless-rope at Ansley Hall Colliery	Chesterf. Mid. Count. Inst.	*Trans.*	3	847	1892
Pike, E. R.	Mining in Perak, Straits Settlements	Cornw. Min. Assoc. Inst.	,,	III.	194	,,
Potts, J. J.	Notes on Screwing Cast-iron and Driving Greenheart Piles at St. Anne's-on-the-Sea, Lancashire	Liv'pool E. Soc.	,,	XIII.	13	,,
Rayner, T. C.	The Manchester Ship Canal Works	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	34	1893
Richardson, H. H.	A new Method of laying Coal Dust	Fed. Inst. Min. Eng.	*Trans.*	4	494	,,
Southern, T. A.	The Estimation of the Actual Effective Pressure of Water Gauge in the Ventilation of Mines	,, ,,	,,	,,	460	,,
Sutcliffe, J. D.	Warming and Ventilation of Public Buildings, with or without Motive Power	Glasgow Phil. Soc.	*Proc.*	XXIII.	196	1892
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Grigor, Rev. W.	Children's Games	„ „ „	„	„	45	„
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Mackay, W.	Notes on Highland Superstitions	" " "	"	"	125	"
Mackenzie, A.	The Gaelic Origin of Local Names	" " "	"	"	9	"
Mansel-Pleydell, J. C.	Kimmeridge Coal Money and other Manufactured Articles from the Kimmeridge Shale	Dorset N. H. A. F. C.	*Proc.*	XIII.	178	1892
" "	An Ancient Interment on the Verne, Portland	" "	"	"	232	"
Matheson, D.	Celtic Place Names	Inverness Sci. Soc.	*Trans.*	III.	296	1893
Mead, Dr. F. H.	On a Widely-spread Superstition in Connection with Hernia in young Children	Som'setsh. A. N. H. Soc.	*Proc.*	XXXVIII.	362	1892
Milligan, S. F.	The Early Christian Architecture of Ireland	Belfast N. H. Phil. Soc.	*Report and Proc.*	For 1893	79	1893
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Ross, A.	Croy Brooches and other Relics	" " "	"	"	126	"
" "	Arrow Heads from New Mexico	" " "	"	"	130	"
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Tannahill, Dr. T. F.	History of the Discoveries made by Convicts while excavating Luton, Horsted, Bridgewood, and Borstal Forts	Rochester N. C.	*Roch. Naturalist*	II.	117, 153	"
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Tooke, W. H.	The Star Lore of the South African Natives	S. African Phil. Soc.	*Trans.*	V.	304	1893
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Tables connected with the Pellian Equation from the point where the work was left by Degen in 1817.—*Report of the Committee, consisting of* Professor A. CAYLEY, Dr. A. R. FORSYTH, Professor A. LODGE, *and* Professor J. J. SYLVESTER. (*Drawn up by* Professor CAYLEY.)

WE have on the Pellian Equation Degen's tables, the title of which is 'Canon Pellianus sive Tabula simplicissimam æquationis celebratissimæ $y^2=ax^2+1$ solutionem pro singulis numeri dati valoribus ab 1 usque ad 1000 in numeris rationalibus iisdemque integris exhibens. Autore Carolo Ferdinando Degen. Hafniæ, apud Gerhardum Bonnierum, MDCCCXVII. 8°. Introductio, pp. v–xxiv. Tabula I. Solutionem æquationis $y^2-ax^2-1=0$ exhibens, pp. 3–106. Tabula II. Solutionem æquationis $y^2-ax^2+1=0$, quotiescunque valor ipsius a talem admiserit, exhibens, pp. 109–112.'

The mode of calculation is explained in the Introduction, and illustrated by the examples of the numbers 209, 173.

As to the first of these the entry in Table I. is

209	14, 2, 5, 3, (2) 1, 13, 5, 8, 11 3220 46551

where the first line gives the expression of $\sqrt{209}$ as a continued fraction, viz., we have

$$\sqrt{209}=14+\frac{1}{2+}\;\frac{1}{5+}\;\frac{1}{3+}\;\frac{1}{2+}\;\frac{1}{3+}\;\frac{1}{5+}\;\frac{1}{2+}\;\frac{1}{28+}\;\frac{1}{2+}\;\&\text{c.},$$

the denominators being 2, 5, 3, (2), 3, 5, 2, then 28, which is the double of the integer part 14, and then again 2, 5, 3, (2), 3, 5, 2, and so on, the parentheses of the (2) being used to indicate that this is the middle term of the period.

The second row gives auxiliary numbers occurring in the calculation of the first row and having a meaning, as will presently appear. Observe that the 11 which comes under the (2) should also be printed in parentheses (11), but this is not done.

The process for the calculation of the x, y is as follows:

209			
14	1	0	+ 1
2	14	1	− 13
5	29	2	+ 5
3	159	11	− 8
(2)	506	35	+ (11)
3	1171	81	− 8
5	4019	278	+ 5
2	21266	1471	− 13
28	46551	3220	+ 1

viz., writing down as a first column the numbers of the first row, and beginning the second column with 1, 14 (14 the number at the head of

the first column), and the third column with 0, 1, we calculate the numbers of the second column, $29=2.14+1$, $159=5.29+14$, $506=3.159+29$, &c., and the numbers of the third column in like manner, $2=2.1+0$, $11=5.2+1$, $35=3.11+2$, &c.; and then writing down as a fourth column the numbers of the second row with the signs $+$, $-$ alternately, we have a series of equations $y^2-ax^2=\pm A$, viz.,

$$\begin{array}{ll} 1^2-209.0^2 & =+\ 1 \\ 14^2-209.1^2 & =-13 \\ 29^2-209.2^2 & =+\ 5 \\ \vdots & \end{array}$$

the last of them being

$$(46551)^2-209(3220)^2=+\ 1$$

this last corresponding as above to the value $+1$, and the numbers 46551 and 3220 being accordingly the y and x given in the fourth and third rows of the table.

As to the second of the foregoing numbers, 173, the only difference is that the period has a double middle term, viz., the entry in the Table I. is

173	13, 6, (1, 1) 1, 4, (13, 13) 190060 2499849

The first row gives the expression of $\sqrt{173}$, viz., that is

$$\sqrt{173}=13+\frac{1}{6+}\ \frac{1}{(1)+}\ \frac{1}{(1)+}\ \frac{1}{6+}\ \frac{1}{26+}\ \&c.,$$

the denominators being 6, 1, 1, 6, then 26 (the double of the integer part 13), and then again 6, 1, 1, 6, and so on. In the second row I remark that Degen prints the parentheses (13, 13) for the double middle term.

The process for the calculation of the x, y is similar to that in the former case, viz., we have

173			
13	1	0	+ 1
6	13	1	− 4
(1	79	6	+13
1)	92	7	−13
6	171	13	+ 4
26	1118	85	− 1

where the second and third columns begin 1, 13 and 0, 1 respectively, and the remaining terms are calculated $79=6.13+1$, $92=1.79+13$, &c., and $6=6.1+0$, $7=1.6+1$, &c.; and then writing down as a fourth column the terms of the second row with the signs $+$, $-$ alternately, we have

$$\begin{array}{ll} 1^2-173.0^2 & =+\ 1 \\ 13^2-173.1^2 & =-\ 4 \\ 79^2-173.6^2 & =+13 \\ \vdots & \end{array}$$

the last equation being

$$(1118)^2-173\,(85)^2=-\ 1$$

the term for the last equation being always in a case such as the present

one, not +1, but −1. The final numbers 1118, 85 are consequently entered not in Table I., but in Table II., viz., the entry in this table is

173	85 1118

and thence we calculate the numbers y, x of Table I., viz., these are

$$2499849=2.(1118)^2+1$$
$$190060=2.1118.85$$

Generally Table II. gives for each value of a, comprised therein, values of x, y, such that $y^2=ax^2-1$, and then writing $y_1=2y^2+1$, $x_1=2xy$, we have

$$y_1{}^2=(2ax^2-1)^2=4a^2x^4-4ax^2+1=a.4x^2(ax^2-1)+1=ax_1{}^2+1$$

so that x_1, y_1 are for the same value of a the values of x, y in Table I.

It is to be remarked that the heading of Table II. is not perfectly accurate, for it purports to give for every value of a, for which a solution exists, a solution of the equation $y^2=ax^2-1$. What it really gives is the solution for each value of a for which the period has a double middle term. But if $a=\alpha^2+1$, then obviously we have a solution $y=\alpha$, $x=1$, and for any such value of a the period has a single middle term, viz., the entry in Table I. is

α^2+1	α, (2α) 1, 1 2α $2\alpha^2+1$

and we in fact have

α^2+1			
α (2α) 2α	1 α $2\alpha^2+1$	0 1 2α	+1 −1 +1

that is

$$1^2-(\alpha^2+1)\,0^2 \quad =+1$$
$$\alpha^2-(\alpha^2+1)\,1^2 \quad =-1$$
$$(2\alpha^2+1)^2-(\alpha^2+1)\,(2\alpha)^2=+1$$

The foregoing instances of the calculation of x, y in the case of the numbers 209 and 173 suggest a table which may be regarded as an extended form of Degen's tables; viz., such a table, from $a=2$ to $a=99$, is as follows:

Specimen of extended form of Table in regard to the Pellian Equation.

a		y	x	y^2-ax^2	a		y	x	y^2-ax^2
2	1 (2) 2	1 1 3	0 1 2	+ 1 − 1 + 1	5	2 (4) 4	1 2 9	0 1 4	+ 1 − 1 + 1
3	1 (1) 2	1 1 2	0 1 1	+ 1 − 2 + 1	6	2 (2) 4	1 2 5	0 1 2	+ 1 − 2 + 1

SPECIMEN OF EXTENDED FORM OF PELLIAN EQUATION TABLE—*continued.*

a		y	x	y^2-ax^2
7	2	1	0	+ 1
	1	2	1	− 3
	(1)	3	1	+ 2
	1	5	2	− 3
	4	8	3	+ 1
8	2	1	0	+ 1
	(1)	2	1	− 4
	4	3	1	+ 1
10	3	1	0	+ 1
	(6)	3	1	− 1
	6	19	6	+ 1
11	3	1	0	+ 1
	(3)	3	1	− 2
	6	10	3	+ 1
12	3	1	0	+ 1
	(2)	3	1	− 3
	6	7	2	+ 1
13	3	1	0	+ 1
	1	3	1	− 4
	(1	4	1	+ 3
	1)	7	2	− 3
	1	11	3	+ 4
	6	18	5	− 1
14	3	1	0	+ 1
	1	3	1	− 5
	2	4	1	+ 2
	1	11	3	− 5
	6	15	4	+ 1
15	3	1	0	+ 1
	(1)	3	1	− 6
	6	4	1	+ 1
17	4	1	0	+ 1
	(8)	4	1	− 1
	8	33	8	+ 1
18	4	1	0	+ 1
	(4)	4	1	− 2
	8	17	4	+ 1
19	4	1	0	+ 1
	2	4	1	− 3
	1	9	2	+ 5
	3	13	3	− 2
	1	48	11	+ 5
	2	61	14	− 3
		170	39	+ 1
20	4	1	0	+ 1
	(2)	4	1	− 4
	8	9	2	+ 1
21	4	1	0	+ 1
	1	4	1	− 5
	1	5	1	+ 4
	(2)	9	2	− 3
	1	23	5	+ 4
	1	32	7	− 5
	8	55	12	+ 1
22	4	1	0	+ 1
	1	4	1	− 6
	2	5	1	+ 3
	(4)	14	3	− 2
	2	61	13	+ 3
	1	136	29	− 6
	8	197	42	+ 1
23	4	1	0	+ 1
	1	4	1	− 7
	(3)	5	1	+ 2
	1	19	4	− 7
	8	24	5	+ 1
24	4	1	0	+ 1
	(1)	4	1	− 8
	8	5	1	+ 1
26	5	1	0	+ 1
	(10)	5	1	− 1
	10	51	10	+ 1
27	5	1	0	+ 1
	(5)	5	1	− 2
	10	26	5	+ 1
28	5	1	0	+ 1
	3	5	1	− 3
	(2)	16	3	+ 4
	3	37	7	− 3
	10	127	24	+ 1
29	5	1	0	+ 1
	2	5	1	− 6
	(1	11	2	+ 5
	1)	16	3	− 3
	2	27	5	+ 2
	10	70	13	− 1
30	5	1	0	+ 1
	(2)	5	1	− 5
	10	11	2	+ 1

Specimen of extended Form of Pellian Equation Table—*continued.*

a		y	x	y^2-ax^2
31	5	1	0	+ 1
	1	5	1	− 6
	1	6	1	+ 5
	3	11	2	− 3
	(5)	39	7	+ 2
	3	206	37	− 3
	1	657	118	+ 5
	1	863	155	− 6
	10	1520	273	+ 1
32	5	1	0	+ 1
	1	5	1	− 7
	(1)	6	1	+ 4
	1	11	2	− 7
	10	17	3	+ 1
33	5	1	0	+ 1
	1	5	1	− 8
	(2)	6	1	+ 3
	1	17	3	− 8
	10	23	4	+ 1
34	5	1	0	+ 1
	1	5	1	− 9
	(4)	6	1	+ 2
	1	29	5	− 9
	10	35	6	+ 1
35	5	1	0	+ 1
	(1)	5	1	−10
	10	6	1	+ 1
37	6	1	0	+ 1
	(12)	6	1	− 1
	12	73	12	+ 1
38	6	1	0	+ 1
	(6)	6	1	− 2
	12	37	6	+ 1
39	6	1	0	+ 1
	(4)	6	1	− 3
	12	25	4	+ 1
40	6	1	0	+ 1
	(3)	6	1	− 4
	12	19	3	+ 1
41	6	1	0	+ 1
	(2	6	1	− 5
	2)	13	2	+ 5
	12	32	5	− 1
42	6	1	0	+ 1
	(2)	6	1	− 6
	12	13	2	+ 1

a		y	x	y^2-ax^2
43	6	1	0	+ 1
	1	6	1	− 7
	1	7	1	+ 6
	3	13	2	− 3
	1	46	7	+ 9
	(5)	59	9	− 2
	1	341	52	+ 9
	3	400	61	− 3
	1	1541	235	+ 6
	1	1941	296	− 7
	12	3482	531	+ 1
44	6	1	0	+ 1
	1	6	1	− 8
	1	7	1	+ 5
	1	13	2	− 7
	(2)	20	3	+ 4
	1	53	8	− 7
	1	73	11	+ 5
	1	126	19	− 8
	12	199	30	+ 1
45	6	1	0	+ 1
	1	6	1	− 9
	2	7	1	+ 4
	(2)	20	3	− 5
	2	47	7	+ 4
	1	114	17	− 9
	12	161	24	+ 1
46	6	1	0	+ 1
	1	6	1	−10
	3	7	1	+ 3
	1	27	4	− 7
	1	34	5	+ 6
	2	61	9	− 5
	(6)	156	23	+ 2
	2	997	147	− 5
	1	2150	317	+ 6
	1	3147	464	− 7
	3	5297	781	+ 3
	1	19038	2807	−10
	12	24335	3588	+ 1
47	6	1	0	+ 1
	1	6	1	− 1
	(5)	7	1	+ 2
	1	41	6	−11
	12	48	7	+ 1
48	6	1	0	+ 1
	(1)	6	1	−12
	12	7	1	+ 1
50	7	1	0	+ 1
	(14)	7	1	− 1
	14	99	14	+ 1

SPECIMEN OF EXTENDED FORM OF PELLIAN EQUATION TABLE—*continued.*

a		y	x	y^2-ax^2
51	7	1	0	+ 1
	(7)	7	1	− 2
	14	50	7	+ 1
52	7	1	0	+ 1
	4	7	1	− 3
	1	29	4	+ 9
	(2)	36	5	− 4
	1	101	14	+ 9
	4	137	19	− 3
	14	649	90	+ 1
53	7	1	0	+ 1
	3	7	1	− 4
	(1	22	3	+ 7
	1)	29	4	− 7
	3	51	7	+ 4
	14	182	25	− 1
54	7	1	0	+ 1
	2	7	1	− 5
	1	15	2	+ 9
	(6)	22	3	− 2
	1	147	20	+ 9
	2	169	23	− 5
	14	485	66	+ 1
55	7	1	0	+ 1
	2	7	1	− 6
	(2)	15	2	+ 5
	2	37	5	− 6
	14	89	12	+ 1
56	7	1	0	+ 1
	(2)	7	1	− 7
	14	15	2	+ 1
57	7	1	0	+ 1
	1	7	1	− 8
	1	8	1	+ 7
	(4)	15	2	− 3
	1	68	9	+ 7
	1	83	11	− 8
	14	151	20	+ 1
58	7	1	0	+ 1
	1	7	1	− 9
	1	8	1	+ 6
	(1	15	2	− 7
	1)	23	3	+ 7
	1	38	5	− 6
	1	61	8	+ 9
	14	99	13	− 1
59		1	0	+ 1
		7	1	−10
		8	1	+ 5
	(7)	23	3	− 2
	2	169	22	+ 5
	1	361	47	−10
	14	530	69	+ 1
60	7	1	0	+ 1
	1	7	1	−11
	(2)	8	1	+ 4
	1	23	3	−11
	14	31	4	+ 1
61	7	1	0	+ 1
	1	7	1	−12
	4	8	1	+ 3
	3	39	5	− 4
	1	125	16	+ 9
	(2	164	21	− 5
	2)	453	58	+ 5
	1	1070	137	− 9
	3	1523	195	+ 4
	4	5639	722	− 3
	1	24079	3083	+12
	14	29718	3805	− 1
62	7	1	0	+ 1
	1	7	1	−13
	(6)	8	1	+ 2
	1	55	7	−13
	14	63	8	+ 1
63	7	1	0	+ 1
	(1)	7	1	−14
	14	8	1	+ 1
65	8	1	0	+ 1
	(16)	8	1	− 1
	16	129	16	+ 1
66	8	1	0	+ 1
	(8)	8	1	− 2
	16	65	8	+ 1
67	8	1	0	+ 1
	5	8	1	− 3
	2	41	5	+ 6
	1	90	11	− 7
	1	131	16	+ 9
	(7)	221	27	− 2
	1	1678	205	+ 9
	1	1899	232	− 7
	2	3577	437	+ 6
	5	9053	1106	− 3
	16	48842	5967	+ 1
68	8	1	0	+ 1
	(4)	8	1	− 4
	16	33	4	+ 1

SPECIMEN OF EXTENDED FORM OF PELLIAN EQUATION TABLE—*continued.*

a		y	x	y^2-ax^2
69	8	1	0	+ 1
	3	8	1	− 5
	3	25	3	+ 4
	1	83	10	−11
	(4)	108	13	+ 3
	1	515	62	−11
	3	623	75	+ 4
	3	2384	297	− 5
	16	7775	936	+ 1
70	8	1	0	+ 1
	2	8	1	− 6
	1	17	2	+ 9
	(2)	25	3	− 5
	1	67	8	+ 9
	2	92	11	− 6
	16	251	30	+ 1
71	8	1	0	+ 1
	2	8	1	− 7
	2	17	2	+ 5
	1	42	5	−11
	(7)	59	7	+ 2
	1	455	54	−11
	2	514	61	+ 5
	2	1483	176	− 7
	16	3480	413	+ 1
72	8	1	0	+ 1
	(2)	8	1	− 3
	16	17	2	+ 1
73	8	1	0	+ 1
	1	8	1	− 9
	1	9	1	+ 8
	(5	17	2	− 3
	5)	94	11	+ 3
	1	487	57	− 8
	1	581	68	+ 9
	16	1068	125	− 1
74	8	1	0	+ 1
	1	8	1	−10
	(1	9	1	+ 7
	1)	17	2	− 7
	1	26	3	+10
	16	43	5	− 1
75	8	1	0	+ 1
	1	8	1	−11
	(1)	9	1	+ 6
	1	17	2	−11
	16	26	3	+ 1
76	8	1	0	+ 1
	1	8	1	−12
	2	9	1	+ 5
	1	26	3	− 8
	1	35	4	+ 9
	5	61	7	− 3
	(4)	340	39	+ 4
	5	1421	163	− 3
	1	7445	854	+ 9
	1	8866	1017	− 8
	2	16311	1871	+ 5
	1	41488	4759	−12
	16	57799	6630	+ 1
77	8	1	0	+ 1
	1	8	1	−13
	3	9	1	+ 4
	(2)	35	4	− 7
	3	79	9	+ 4
	1	272	31	−13
	16	351	40	+ 1
78	8	1	0	+ 1
	1	8	1	−14
	(4)	9	1	+ 3
	1	44	5	−14
	16	53	6	+ 1
79	8	1	0	+ 1
	1	8	1	−15
	(7)	9	1	+ 2
	1	71	8	−15
	16	80	9	+ 1
80	8	1	0	+ 1
	(1)	8	1	−16
	16	9	1	+ 1
82	9	1	0	+ 1
	(18)	9	1	− 1
	18	163	18	+ 1
83	9	1	0	+ 1
	(9)	9	1	− 2
	18	82	9	+ 1
84	9	1	0	+ 1
	(6)	9	1	− 3
	18	55	6	+ 1
85	9	1	0	+ 1
	4	9	1	− 4
	(1	37	4	+ 9
	1)	46	5	− 9
	4	83	9	+ 4
	18	378	41	− 1
86	9	1	0	+ 1
	3	9	1	− 5
	1	28	3	+10

SPECIMEN OF EXTENDED FORM OF PELLIAN EQUATION TABLE—*continued.*

a		y	x	y^2-ax^2
	1	37	4	− 7
	1	65	7	+11
	(8)	102	11	− 2
	1	881	95	+11
	1	983	106	− 7
	1	1864	201	+10
	3	2847	307	− 5
	18	10405	1122	+ 1
87	9	1	0	+ 1
	(3)	9	1	− 6
	18	28	3	+ 1
88	9	1	0	+ 1
	2	9	1	− 7
	1	19	2	+ 9
	(1)	28	3	− 8
	1	47	5	+ 9
	2	75	8	− 7
	18	197	21	+ 1
89	9	1	0	+ 1
	2	9	1	− 8
	(3	19	2	+ 5
	3)	66	7	− 5
	2	217	23	+ 8
	18	500	53	− 1
90	9	1	0	+ 1
	(2)	9	1	− 9
	18	19	2	+ 1
91	9	1	0	+ 1
	1	9	1	−10
	1	10	1	+ 9
	5	19	2	− 3
	(1)	105	11	+14
	5	124	13	− 3
	1	725	76	+ 9
	1	849	89	−10
	18	1574	165	+ 1
92	9	1	0	+ 1
	1	9	1	−11
	1	10	1	+ 3
	2	19	2	− 7
	(4)	48	5	+ 4
	2	211	22	− 7
	1	470	49	+ 3
	1	681	71	−11
	18	1151	120	+ 1
93	9	1	0	+ 1
	1	9	1	−12
	1	10	1	+ 7
	1	19	2	−11
	4	29	3	+ 4
	(6)	135	14	− 3
	4	839	87	+ 4
	1	3491	362	−11
	1	4330	449	+ 7
	1	7821	811	−12
	18	12151	1260	+ 1
94	9	1	0	+ 1
	1	9	1	−13
	2	10	1	+ 6
	3	29	3	− 5
	1	97	10	+ 9
	1	126	13	−10
	5	223	23	+ 3
	1	1241	128	−15
	(8)	1464	151	+ 2
	1	12953	1336	−15
	5	14417	1487	+ 3
	1	85038	8771	−10
	1	99455	10258	+ 9
	3	1 84493	19029	− 5
	2	6 52934	67345	+ 6
	1	14 90361	1 53719	−13
	18	21 43295	2 21064	+ 1
95	9	1	0	+ 1
	1	9	1	−14
	(2)	10	1	+ 5
	1	29	3	−14
	18	39	4	+ 1
96	9	1	0	+ 1
	1	9	1	−15
	(3)	10	1	+ 4
	1	39	4	−15
	18	49	5	+ 1
97	9	1	0	+ 1
	1	9	1	−16
	5	10	1	+ 3
	1	59	6	−11
	1	69	7	+ 8
	(1	128	13	− 9
	1)	197	20	+ 9
	1	325	33	− 8
	1	522	53	+11
	5	847	86	− 3
	1	4757	483	+16
	18	5604	569	− 1
98	9	1	0	+ 1
	1	9	1	−17
	(8)	10	1	+ 2
	1	89	9	−17
	18	99	10	+ 1
99	9	1	0	+ 1
	(1)	9	1	−18
	18	10	1	+ 1

The meaning hardly requires explanation; for each number a we have a series of pairs of increasing numbers, y, x, satisfying a series of equations $y^2=ax^2\pm b$; thus

$a=14$

y	x	y^2-ax^2
1	0	$1-14.0 = 1$
3	1	$9-14.1 = -5$
4	1	$16-14.1 = +2$
11	3	$121-14.9 = -5$
15	4	$225-14.16 = +1$

The following table, calculated under the superintendence of the Committee, extends from $a=1001$ to $a=1500$ (square numbers omitted); it is (with slight typographical variations) nearly but not exactly in the form of Degen's Table I., the chief difference being that for a number a having a double middle term, or of the form a^2+1 (such number being further distinguished by an asterisk), the x, y entered in the table are the solutions, *not* of the equation $y^2=ax^2+1$, but of the equation $y^2=ax^2-1$. As remarked above, if we have $y^2=ax^2-1$, then writing $y_1=2y^2+1$ and $x_1=2xy$, we obtain $y_1{}^2=ax_1{}^2+1$.

Moreover, for each value of a, in the first line, the first term, which is the integer part of $\sqrt{a}$, is separated from the other by a semicolon, and the 1, which is the corresponding first term of the second line, is omitted.

The calculations were made by C. E. Bickmore, M.A., of New College, Oxford: his values for x and y have been revised as presently mentioned, but it has been assumed that his values for the periods and subsidiary numbers (forming the first and second lines of each division of the table) are accurate; in fact, any error therein would cause the resulting values of x and y to be wildly erroneous; but (except in a single instance which was accounted for) the errors in x and y were in every case in a single figure or two or three figures only.

The values of x and y were in every case examined by substitution in the equation ($y^2=ax^2+1$, or $y^2=ax^2-1$, as the case may be) which should be satisfied by them. These verifications were for the most part made by A. Graham, M.A., of the Observatory, Cambridge. As already mentioned, some errors were detected, and these have been, of course, corrected. The values of x, y given in the table thus satisfy in every case the proper equation $y^2=ax^2+1$, or $y^2=ax^2-1$; on the ground above referred to it is believed that the periods and subsidiary numbers are also accurate.

It may be remarked, in regard to the verification of the equation $y^2=ax^2\pm1$ for large values of x and y, it is in practice easier and safer to calculate $ax^2\pm1$, and then to compare the square root thereof with the given value of y, than to further calculate the value of y^2.

The Table 1001 to 1500.

1001	31; 1, 1, 1, 3, 3, 2, (4) 40, 23, 35, 16, 17, 25, (13)	33532 10 60905
1002	31; 1, 1, 1, 8, 2, 1, 1, 1, 3, (10) 41, 22, 39, 7, 23, 31, 26, 33, 17, (6)	65 35248 2068 69247
1003	31; 1, 2, (31) 42, 21, (2)	285 9026
1004	31; 1, 2, 5, 2, 2, 1, 7, 4, 1, 2, 1, 11, 1, (14) 43, 20, 11, 25, 19, 41, 8, 13, 40, 17, 44, 5, 55, (4)	85 24164 59730 2700 96330 24199
1005	31; 1, 2, 2, 1, 5, 15, 1, 2, (12) 44, 19, 20, 39, 11, 4, 41, 21, (5)	930 59568 29501 49761
1006	31; 1, 2, 1, 1, 5, 1, 3, 2, 1, 1, 1, 1, 1, 9, 1, 20, 4, 5, 1, 1, 12, 6, 1, (30) 45, 18, 29, 33, 10, 43, 15, 22, 31, 27, 30, 25, 37, 6, 55, 3, 15, 11, 30, 33, 5, 9, 53, (2)	4 45346 14025 55749 21748 141 25267 56378 02146 05455
1007	31; 1, 2, (1) 46, 17, (38)	15 476
1008	31; 1, (2) 47, (16)	4 127
1009*	31; 1, (3, 3) 48, (15, 15)	17 540
1010*	31; 1, 3, (1, 1) 49, 14, (31, 31)	41 1303
1011	31; 1, 3, 1, (9) 50, 13, 47, (6)	265 8426
1012	31; 1, 4, 3, 6, 1, 3, 8, 1, (4) 51, 12, 19, 9, 43, 16, 7, 48, (11)	1013 02110 32226 17399
1013*	31; 1, 4, 1, 4, 15, 1, 2, (2, 2) 52, 11, 44, 13, 4, 43, 19, (23, 23)	123 52985 3931 66618

1014	31 ; 1, 5, 2, 1, 1, 1, 1, (20) 53, 10, 23, 30, 29, 25, 38, (3)	1 46266 46 56965
1015	31 ; 1, 6, 10, (2) 54, 9, 6, (29)	11076 3 52871
1016	31 ; 1, (6) 55, (8)	8 255
1017	31 ; 1, 8, 7, 1, 6, 4, 1, 3, 5, 1, 1, (6) 56, 7, 8, 49, 9, 13, 41, 16, 11, 31, 32, (9)	9 09655 84992 290 09322 97217
1018*	31 ; 1, 9, 1, 1, 1, 6, 2, (3, 3) 57, 6, 39, 23, 38, 9, 26, (17, 17)	27 28333 870 50499
1019	31 ; 1, 11, 1, 3, 1, 1, 1, 3, 8, 1, 5, 2, (31) 58, 5, 47, 14, 35, 25, 34, 17, 7, 49, 10, 29, (2)	19 07764 36539 608 99233 21730
1020	31 ; 1, (14) 59, (4)	16 511
1021*	31 ; 1, 20, 3, 6, 1, 3, 2, 1, 1, 12, 5, 4, 15, 1, 2, 1, 4, 1, 1, 2, 1, 1, 1, (5, 5) 60, 3, 20, 9, 44, 15, 23, 27, 36, 5, 12, 15, 4, 45, 17, 41, 12, 33, 29, 20, 33, 25, 36, (11, 11)	98 65001 29666 69564 06909 3152 17280 37258 48825 15030
1022	31 ; 1, (30) 61, (2)	32 1023
1023	31 ; (1) (62)	1 32
1025*	32 ; (64) (1)	1 32
1026	32 ; (32) (2)	32 1025
1027	32 ; 21, 2, 1, 6, 2, (4) 3, 22, 39, 9, 27, (13)	41 54868 1331 50393

1028	32; 16) (4)	16 513
1029	32; 12, 1, 4, 2, 2, 1, 3, 15, 1, 3, 2, 1, (20) 5, 49, 12, 25, 20, 37, 17, 4, 47, 15, 20, 43, (3)	303 57068 95884 9737 94964 66615
1030	32; 10, 1, 2, 6, 1, 3, 1, 2, 1, 1, 2, 2, (12) 6, 41, 21, 9, 45, 14, 39, 19, 31, 30, 21, 26, (5)	2 75539 87434 88 43070 11291
1031	32; 9, 6, 3, 4, 1, 1, 1, 1, 1, 12, 4, 1, 1, (31) 7, 10, 19, 13, 35, 26, 31, 25, 38, 5, 14, 29, 35, (2)	2029 75370 82877 65173 74486 64200
1032	32; (8) 8)	8 257
1033*	32; 7, 7, 1, 8, 3, 3, 1, 2, 3, 2, 2, 1, 1, 1, 2, (21, 21) 9, 8, 51, 7, 19, 16, 37, 21, 17, 24, 21, 32, 27, 31, 24, (3, 3)	5 81389 30460 24093 186 86036 75961 74196
1034	32; 6, 2, (2) 10, 25, (22)	494 15885
1035	32; 5, (1) 11, (46)	35 1126
1036	32; 5, 2, 1, 6, (2) 12, 21, 40, 9, (28)	26322 8 47225
1037*	32; 4, 1, 15, (3, 3) 13, 49, 4, (19, 19)	64805 20 86882
1038	32; 4, 1, 1, 2, 2, 1, 2, (10) 14, 33, 29, 22, 21, 34, 23, (6)	4 78126 154 04267
1039	32; 4, 3, 1, 1, 5, 3, 2, 2, 21, 12, 1, 5, 1, 1, 10, 4, 1, 6, 2, 1, 3, 1, 1, 15, 17, 30, 33, 11, 18, 23, 26, 3, 5, 51, 10, 31, 33, 6, 13, 46, 9, 22, 37, 15, 34, 27, 1, 1, 1, 1, (31) 29, 30, 25, 39, (2)	1 53006 74275 15667 18643 06921 49 31946 34979 07633 93486 37520
1040	32; (4) (16)	4 129

1041	32; 3, 1, 3, 1, 1, 4, 2, 2, 7, 1, 1, 1, 12, 3, 1, (20) 17, 40, 15, 31, 32, 13, 24, 25, 8, 39, 23, 40, 5, 16, 47, (3)	2389 36879 43492 77091 86499 27575
1042*	32; 3, (1, 1) 18, (31, 31)	25 807
1043	32; 3, 2, 1, 1, 1, 1, (8) 19, 22, 31, 29, 26, 37, (7)	17864 5 76927
1044	32; 3, 4, 1, 1, 1, 3, 2, 1, 1, (6) 20, 13, 36, 25, 35, 16, 23, 28, 35, (9)	59 45940 1921 19201
1045	32; 3, 15, 1, (4) 21, 4, 51, (11)	14112 4 56191
1046	32; 2, 1, 12, 3, 1, 2, 1, 1, 1, 5, 1, 5, (32) 22, 41, 5, 17, 38, 19, 34, 25, 37, 10, 47, 11, (2)	12 32778 42162 398 70425 10565
1047	32; 2, 1, 3, 1, (20) 23, 37, 14, 49, (3)	4228 1 36807
1048	32; 2, 1, 2, 6, 1, 4, 1, 1, (7) 24, 33, 23, 9, 47, 12, 31, 33, (8)	32 42859 1049 80517
1049*	32 2, 1, 1, 2, 1, 4, 3, 1, 5, 7, 1, (12, 12) 25, 29, 32, 19, 40, 13, 16, 43, 11, 8, 53, (5, 5)	4 74354 09493 153 63508 25620
1050	32; 2, 2, (10) 26, 25, (6)	270 8749
1051	32; 2, 2, 1, 1, 2, 4, 4, 10, 1, 1, 3, 12, 1, 2, 6, 7, 21, 2, 8, 1, 3, 2, 2, 27, 21, 31, 30, 23, 14, 15, 6, 35, 29, 18, 5, 42, 21, 10, 9, 3, 30, 7, 46, 15, 25, 19, 1, (31) 45, (2)	95 53827 66460 01506 59129 73250 2 94697 22410 66655 86570 86507
1052	32; 2, 3, 3, 7, 1, 4, 9, (16) 28, 17, 19, 8, 47, 13, 7, (4)	11935 79112 3 87132 00767
1053	32; 2, (4) 29, (13)	20 649

1054	32; 2, 6, 1, 2, 1, 1, 4, 2, 2, 1, 1, 1, 3, 1, 2, 3, 4, (32) 30, 9, 42, 19, 30, 33, 13, 25, 21, 33, 26, 35, 15, 38, 21, 18, 15, (2)	10335 86450 05416 3 35557 62560 56895
1055	32; 2, (12) 31, (5)	52 1689
1056	32; (2) (32)	2 65
1057	32; 1, 1, 21, 5, 1, 6, 2, 1, 1, 3, 2, 7, 1, 2, 4, 1, 1, 1, (8) 33, 32, 3, 11, 48, 9, 24, 29, 33, 16, 27, 8, 41, 21, 13, 37, 24, 39, (7)	7 37084 02001 32992 239 63733 95685 29407
1058	32; 1, 1, 8, 1, 3, 1, 3, (32) 34, 31, 7, 47, 14, 41, 17, (2)	40 53146 1318 36323
1059	32; 1, 1, 5, 2, 2, 2, 1, 2, 3, 1, (31) 35, 30, 11, 25, 23, 21, 35, 22, 15, 49, (2)	1838 68081 59834 86610
1060	32; 1, 1, 3, 1, 5, 7, (16) 36, 29, 15, 44, 11, 9, (4)	22 64856 737 38369
1061*	32; 1, 1, 2, 1, 12, 3, 5, 1, 1, 2, 15, 1, 8, 2, 1, 2, (1, 1) 37, 28, 19, 44, 5, 20, 11, 35, 28, 25, 4, 55, 7, 23, 35, 20, (31, 31)	28370 82899 91521 9 24122 86971 11530
1062	32; 1, 1, 2, 3, (32) 38, 27, 23, 19, (2)	9418 3 06917
1063	32; 1, 1, 1, 1, 10, 3, 1, 2, 1, 6, 1, 1, 21, 4, 1, (31) 39, 26, 27, 37, 6, 17, 39, 18, 43, 9, 31, 34, 3, 13, 51, (2)	5353 15274 12685 1 74532 48310 97224
1064	32; 1, 1, 1, (1) 40, 25, 31, (28)	21 685
1065	32; 1, 1, 1, 2, 1, 3, 2, 1, 5, (4) 41, 24, 35, 19, 39, 16, 21, 40, 11, (15)	25 33160 826 67999
1066*	32; 1, 1, 1, 5, 1, 6, (2, 2) 42, 23, 39, 10, 49, 9, (25, 25)	1 05205 34 34907

1067	32; 1, (1) 43, (22)	3 98
1068	32; 1, 2, 7, 1, 5, (16) 44, 21, 8, 49, 11, (4)	3 53094 115 39207
1069*	32; 1, 2, 3, 1, 1, 21, 4, 3, 5, 7, 12, 1, 15, 2, 2, 1, 3, 1, 1, 1, 4, 1, (4, 4) 45, 20, 17, 29, 36, 3, 15, 19, 12, 9, 5, 57, 4, 27, 20, 39, 15, 36, 25, 37, 12, 45, (13, 13)	186 40986 37841 77726 15285 6094 77590 16096 85726 12782
1070	32; 1, 2, 2, 5, 1, 1, (12) 46, 19, 26, 11, 31, 34, (5)	90138 29 48491
1071	32; 1, 2, 1, 1, 1, (6) 47, 18, 35, 25, 38, (9)	880 28799
1072	32; 1, 2, 1, 6, 1, 1, 8, 1, 4, 1, 1, (3) 48, 17, 44, 9, 32, 33, 7, 49, 12, 33, 31, (16)	1457 20107 47710 81927
1073*	32; 1, 3, (9, 9) 49, 16, (7, 7)	1385 45368
1074	32; 1, 3, 2, 1, 1, 2, (32) 50, 15, 23, 31, 30, 25, (2)	1 06476 34 89425
1075	32; 1, 3, 1, 2, 3, 10, 1, 1, 1, 2, 2, 6, (1) 51, 14, 39, 21, 19, 6, 39, 25, 34, 21, 26, 9, (50)	51504 12729 16 88675 74226
1076	32; 1, 4, (16) 52, 13, (4)	410 13449
1077	32; 1, 4, 2, 15, 1, (20) 53, 12, 29, 4, 59, (3)	7 16760 235 22399
1078	32; 1, (4) 54, (11)	6 197
1079	32; 1, 5, 1, 1, 2, 2, 4, 3, 1, (1) 55, 10, 35, 29, 22, 25, 14, 17, 35, (26)	54 97325 1805 76876

1080	32 ; 1, 6, (3) 56, 9, (20)	161 5291
1081	32 ; 1, 7, 4, 3, 1, 6, 1, 1, 5, 2, 3, 1, 12, 2, 1, 1, 1, 21, 3, 2, (2) 57, 8, 15, 16, 45, 9, 33, 32, 11, 27, 15, 48, 5, 24, 33, 25, 40, 3, 19, 24, (23)	8918 12221 87280 07648 2 93215 05610 17151 19615
1082*	32 ; 1, 8, 2, 2, 2, (1, 1) 58, 7, 26, 23, 22, (31, 31)	38369 12 62101
1083	32 ; 1, (9) 59, (6)	11 362
1084	32 ; 1, 12, 5, 2, 2, 3, 2, 6, 1, 7, 2, 1, 2, 1, 3, 1, 1, 1, 21, 3, 4, (16) 60, 5, 12, 25, 24, 17, 27, 9, 51, 8, 23, 36, 19, 40, 15, 37, 24, 41, 3, 20, 15, (4)	8 17041 27029 09269 93200 269 00393 64204 05379 19999
1085	32 ; 1, 15, (2) 61, 4, (31)	544 17919
1086	32 ; 1, (20) 62, (3)	22 725
1087	32 ; 1, (31) 63, (2)	33 1088
1088	32 ; (1) (64)	1 33
1090*	33 ; (66) (1)	1 33
1091	33 ; (33) (2)	33 1090
1092	33 ; (22) (3)	22 727
1093*	33 ; 16, (1, 1) 4, (33, 33)	545 18018

1094	33 ; 13, 4, 1, 1, 1, 5, 2, 1, 2, 3, 9, 6, 1, 1, (32) 5, 14, 37, 25, 38, 11, 23, 35, 22, 19, 7, 10, 31, 35, (2)	45043 80474 67914 14 89854 05815 38085
1095	33 ; (11) (6)	11 364
1096	33 ; 9, 2, 3, 1, (15) 7, 28, 15, 49, (4)	1 19595 39 59299
1097*	33 ; 8, 3, 1, 3, 2, 1, (1, 1) 8, 17, 41, 16, 23, 32, (29, 29)	6 34621 210 19276
1098	33 ; 7, 2, 1, (6) 9, 22, 41, (9)	3564 1 18097
1099	33 ; 6, 1, 1, 1, 1, 2, 21, 1, 2, 1, 1, 6, 1, (3) 10, 37, 27, 30, 31, 25, 3, 46, 19, 30, 35, 9, 47, (14)	4 80575 45715 159 31638 15326
1100	33 ; (6) (11)	6 199
1101	33 ; 5, 1, 1, 16, (22) 12, 31, 35, 4, (3)	7 32732 243 13015
1102	33 ; 5, 10, 1, 6, (2) 13, 6, 53, 9, (29)	3 42882 113 82443
1103	33 ; 4, 1, 2, 1, 2, 3, 1, 1, 5, 2, 9, (33) 14, 41, 19, 37, 22, 17, 31, 34, 11, 29, 7, (2)	7 06456 11145 234 62427 45024
1104	33 ; 4, 2, (2) 15, 25, (23)	234 7775
1105*	33 ; 4, (7, 7) 16, (9, 9)	857 28488
1106	33 ; 3, 1, (8) 17, 46, (7)	152 5055

1107	33; 3, 1, 2, 7, (33) 18, 37, 23, 9, (2)	2 18295 72 63026
1108	33; 3, 2, 21, 1, 3, 4, 1, 6, 1, 1, 2, 2, 1, 3, 2, 5, 9, 3, (16) 19, 28, 3, 49, 16, 13, 48, 9, 36, 29, 23, 21, 39, 16, 27, 12, 7, 21, (4)	4781 20058 69390 13510 1 59150 07379 89804 75849
1109*	33; 3, 3, 5, 1, 3, 13, 16, 1, 1, 2, 1, 4, (2, 2) 20, 19, 11, 44, 17, 5, 4, 37, 29, 20, 41, 13, (25, 25)	1832 35957 38617 61020 60015 42610
1110	33; 3, (6) 21, (10)	60 1999
1111	33; (3) (22)	3 100
1112	33; 2, 1, (7) 23, 41, (8)	75 2501
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1277*	35; 1, 2, 1, 3, 2, 5, 17, 1, 2, (6, 6) 52, 19, 44, 17, 29, 13, 4, 47, 23, (11, 11)	40427 42285 14 44679 48482

1278	35; 1, (2) 53, (18)	4 143
1279	35; 1, 3, 4, 1, 1, 13, 1, 3, 23, 1, 1, 2, 2, 1, 5, 1, 3, 1, 11, 7, 1, 6, 3, 54, 17, 15, 33, 38, 5, 51, 18, 3, 41, 30, 25, 22, 45, 11, 50, 15, 53, 6, 9, 55, 10, 19, 1, 1, 1, 1, 1, 2, (35) 37, 30, 33, 31, 34, 27, (2)	7 89404 78828 27783 39935 75041 282 31569 87094 18598 91612 56000
1280	35; 1, 3, 2, (17) 55, 16, 31, (4)	1449 51841
1281	35; 1, 3, 1, 3, 1, 2, 13, 1, (22) 56, 15, 47, 16, 41, 25, 5, 64, (3)	220 81748 7903 29175
1282	35; 1, 4, 7, 1, 3, 9, 1, (34) 57, 14, 9, 49, 18, 7, 63, (2)	952 47138 34103 26403
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1284	35; 1, (4) 59, (12)	6 215
1285*	35; 1, 5, 1, 1, 7, 2, 2, 1, 17, 4, 1, 2, 1, (1, 1) 60, 11, 35, 36, 9, 29, 21, 49, 4, 15, 44, 21, 36, (31, 31)	24 48426 94225 877 68507 57318
1286	35; 1, 6, 5, 2, 1, 2, 13, 1, (34 61, 10, 13, 25, 37, 26, 5, 65, (2)	7072 64778 2 53631 10565
1287	35; 1, (6) 62, (9)	8 287
1288	35; 1, (7) 63, (8)	9 323
1289*	35; 1, 9, 3, 1, 2, 8, 1, 1, 1, 1, 2, 1, 1, 13, 1, 3, (1, 1) 64, 7, 19, 40, 25, 8, 41, 29, 32, 35, 23, 31, 40, 5, 53, 16, (35, 35)	835 94139 33853 30012 50804 21900
1290	35; 1, (10) 65, (6)	12 431

1291	35 ; 1, 13, 2, 1, 1, 2, 3, 1, 1, 1, 1, 4, 1, 11, 6, 2, 4, 3, 23, 1, 1, 1, 66, 5, 27, 33, 34, 25, 18, 37, 31, 30, 39, 13, 55, 6, 11, 30, 15, 22, 3, 45, 26, 41, 4, 7, 1, 3, 2, 1, 6, 2, (35) 15, 9, 50, 17, 23, 45, 10, 33, (2)	1974 27745 80291 79860 94899 51267 70936 75339 57910 18687 74456 08410
1292	35 ; 1, (16) 67, (4)	18 647
1293	35 ; 1, (22) 68, (3)	24 863
1294	35 ; 1, (34) 69, (2)	36 1295
1295	35 ; (1) (70)	1 36
1297*	36 ; (72) (1)	1 36
1298	36 ; (36) (2)	36 1297
1299	36 ; (24) (3)	24 865
1300	36 ; (18) (4)	18 649
1301*	36 ; 14, 2, (2, 2) 5, 29, (25, 25)	6025 2 17318
1302	36 ; (12) (6)	12 433
1303	36 ; 10, 3, 2, 1, 23, 2, 1, 2, 1, 3, 3, 1, 1, 7, 2, 5, 11, 1, 5, 1, 1, 1, 4, 7, 21, 22, 49, 3, 26, 39, 21, 43, 18, 19, 33, 38, 9, 31, 13, 6, 57, 11, 42, 27, 41, 14, 1, 1 (35) 33, 39 (2)	10127 26314 51893 46887 71461 3 65564 74232 60608 71132 28808

1304	36 ; (9) (8)	9 325
1305	36 ; (8) (9)	8 289
1306*	36 ; 7, 4, 1, 2, 11, 1, 2, 4, 2, 9, 1, (7, 7) 10, 15, 42, 25, 6, 47, 23, 15, 31, 7, 58, (9, 9)	862 68151 05389 31176 12101 50515
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1308	36 ; (6) (12)	6 217
1309	36 ; 5, 1, 1, 4, 3, 1, 1, 2, 3, 17, 1, 3, 1, 7, (4) 13, 36, 35, 15, 19, 36, 33, 25, 21, 4, 55, 15, 52, 9, (17)	2219 92217 38044 80317 01740 72265
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1312	36 ; 4, 1, 1, (17) 16, 33, 39, (4)	1467 53137
1313*	36 ; (4, 4) (17, 17)	17 616
1314	36 ; (4) (18)	4 145
1315	36 ; 3, 1, 4, 11, 1, 7, (7) 19, 46, 15, 6, 59, 9, (10)	244 74351 8875 11646
1316	36 ; 3, 1, 1, 1, 1, 2, 3, (2) 20, 37, 31, 32, 35, 25, 19, (28)	65508 23 76415

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1321*	36; 2, 1, 8, 2, 2, 1, 1, 3, 1, 23, 2, 4, 2, 1, 4, 6, 2, 1, 1, 7, 2, (14, 14) 25, 45, 8, 29, 24, 33, 37, 16, 55, 3, 32, 15, 24, 43, 15, 11, 27, 31, 40, 9, 33, (5, 5)	14 70631 38627 19611 69925 534 50926 71539 66127 96432
1322*	36; 2, 1, 3, 1, (1, 1) 26, 41, 17, 38, (31, 31)	821 29851
1323	36; 2, 1, 2, 7, 1, 2, (2) 27, 37, 26, 9, 47, 22, (27)	1 00360 36 50401
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1325*	36; (2, 2) (29, 29)	5 182
1326	36; 2, 2, (2) 30, 25, (26)	70 2549
1327	36; 2, 2, 1, (35) 31, 21, 51, (2)	1785 65024
1328	36; 2, 3, 1, (3) 32, 17, 47, (16)	369 13447

1329	36 ; 2, 5, 8, 1, 13, 1, 2, 4, 4, 1, 1, 1, 2, 2, 1, 1, 6, (24) 33, 13, 8, 61, 5, 48, 23, 16, 15, 40, 29, 37, 24, 25, 32, 39, 11, (3)	19 32883 59509 34116 704 64145 63882 01495
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1332	36 ; (2) (36)	2 73
1333	36 ; 1, 1, 23, 1, 5, 7, 1, 17, 2, 1, 1, 1, 5, (2) 37, 36, 3, 59, 12, 9, 61, 4, 27, 36, 29, 41, 12, (31)	904 20166 84140 33012 64933 32151
1334	36 ; 1, 1, 9, 1, 13, 1, 2, 2, 1, 1, (2) 38, 35, 7, 62, 5, 49, 22, 25, 34, 35, (23)	864 08256 31559 72095
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1336	36 ; 1, 1, 4, 2, 1, 2, 2, 1, 4, 5, 1, 7, 3, 1, 1, (8) 40, 33, 15, 25, 39, 24, 23, 44, 15, 12, 55, 9, 20, 33, 39, (8)	174 56099 99622 6380 43737 19695
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1338	36 ; 1, 1, 2, 1, 2, 10, (12) 42, 31, 23, 39, 26, 7, (6)	4 73194 173 08813
1339	36 ; 1, 1, 2, 4, 1, (4) 43, 30, 27, 14, 51, (13)	4104 1 50175
1340	36 ; 1, 1, 1, 1, 6, (18) 44, 29, 31, 40, 11, (4)	19932 7 29631
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1342	36; 1, 1, 1, (2) 46, 27, 39, (22)	30 1099
1343	36; 1, 1, 1, 4, 1, (35) 47, 26, 43, 13, 59, (2)	10591 3 88128
1344	36; 1, 1, 1, (17) 48, 25, 47, (4)	165 6049
1345	36; 1, 2, (14) 49, 24, (5)	132 4841
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1347	36; 1, 2, 2, 1, 5, 1, (35) 51, 22, 23, 46, 11, 61, (2)	1 64753 60 46682
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1350	36; 1, 2, 1, 7, 2, (2) 54, 19, 50, 9, 29, (25)	12804 4 70449
1351	36; 1, 3, (10) 55, 18, (7)	168 6175
1352	36; 1, 3, 2, 1, (17) 56, 17, 23, 49, (4)	3107 1 14243
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1367	36; 1, (35) 71, (2)	37 1368

1368	36 ; (1) (72)	1 37
1370*	37 ; (74) (1)	1 37
1371	37 ; (37) (2)	37 1370
1372	37 ; 24, 1, 2, 7, 1, 8, 2, 1, 1, 1, 2, 2, 5, 1, 3, (18) 3, 49, 24, 9, 59, 8, 27, 36, 31, 37, 24, 29, 12, 49, 19, (4)	92062 30469 34552 34 10035 48679 27167
1373*	37 ; 18, (1, 1) 4, (37, 37)	685 25382
1374	37 ; 14, 1, 4, 2, 1, 3, 4, 1, 2, (24) 5, 57, 14, 25, 42, 19, 15, 43, 26, (3)	41422 89074 15 35443 25045
1375	37 ; 12, 2, 1, 7, 1, 1, 3, 2, 1, 2, (6) 6, 25, 46, 9, 39, 34, 19, 25, 39, 26, (11)	24090 73932 8 93308 52249
1376	37 ; 10, 1, 1, 2, 2, 3, 1, (17) 7, 41, 32, 25, 28, 17, 55, (4)	58 37205 2165 28049
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1378*	37 ; 8, (4, 4) 9, (17, 17)	1153 42801
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1380	37 ; 6, 1, (2) 11, 49, (20)	182 6761
1381*	37 ; 6, 5, 1, 1, 4, 2, 2, 3, 3, 4, 14, 1, 1, 1, 2, 1, 1, 2, 1, 24, 12, 13, 37, 36, 15, 28, 27, 20, 21, 17, 5, 45, 28, 39, 23, 35, 36, 21, 52, 3, 18, 1, 1, 5, 1, 2, 7, 1, 9, 1, 2, 1, (4, 4) 4, 39, 35, 12, 45, 25, 9, 60, 7, 51, 20, 47, (15, 15)	5 76794 95050 76394 67609 26124 87905 214 34743 40923 77992 50381 97708 76282

1382	37 ; 5, 1, 2, 2, 1, 1, (36) 13, 46, 23, 26, 31, 43, (2)	3 49782 130 03237
1383	37 ; 5, 3, 2, 1, (11) 14, 21, 23, 49, (6)	34821 12 94948
1384	37 ; 4, 1, (17) 15, 57, (4)	465 17299
1385*	37 ; 4, 1, 1, 1, (3, 3) 16, 41, 29, 40, (19, 19)	2797 1 04092
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1387	37 ; 4, 8, (37) 18, 9, (2)	40557 15 10442
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1389	37 ; 3, 1, 2, 2, (24) 20, 43, 23, 31, (3)	16796 6 25975
1390	37 ; 3, 1, 1, 6, 4, 1, 4, 1, 1, 11, 1, 7, 2, 1, 2, 1, (6) 21, 34, 39, 11, 15, 51, 14, 35, 39, 6, 61, 9, 26, 41, 21, 49, (10)	6165 38516 07582 2 29862 22854 32981
1391	37 ; 3, 2, 1, 1, 1, 6, 1, (4) 22, 25, 38, 29, 43, 10, 55, (13)	2 43492 90 81305
1392	37 ; 3, (4) 23, (16)	42 1567
1393	37 ; 3, (10) 24, (7)	96 3583
1394	37 ; 2, 1, (36) 25, 49, (2)	336 12545

1395	37; 2, 1, 6, (8) 26, 45, 11, (9)	3320 1 24001
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1397	37; 2, 1, 1, 1, 10, 18, 1, 1, 2, (6) 28, 37, 29, 44, 7, 4, 43, 31, 28, (11)	4289 66440 1 60332 48351
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1403	37; 2, 5, 3, (1) 34, 13, 19, (46)	1995 74726
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1405	37; 2, (14) 36, (5)	60 2249
1406	37; (2) (37)	2 75
1407	37; 1, 1, (24) 38, 37, (3)	100 3751

1408	37; 1, 1, 10, 4, 1, 1, 2, 7, 1, (17) 39, 36, 7, 16, 39, 33, 28, 9, 63, (4)	3211 01529 1 20487 97377
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1417*	37; 1, 1, 1, 4, 24, 1, 7, (2, 2) 48, 27, 43, 16, 3, 64, 9, (29, 29)	435 72829 16402 14636
1418*	37; 1, 1, 1, (10, 10) 49, 26, 47, (7, 7)	1033 38899
1419	37; 1, 2, (37) 50, 25, (2)	339 12770
1420	37; 1, 2, 6, 1, 1, (14) 51, 24, 11, 36, 39, (5)	25338 9 54809

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1422	37; 1, 2, 2, 3, 1, 3, 5, (8) 53, 22, 29, 18, 47, 19, 14, (9)	31 79792 1199 08097
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1426	37; 1, 3, 4, 1, 3, 1, 1, 1, (2) 57, 18, 15, 50, 17, 41, 30, 39, (23)	2 61132 98 60975
1427	37; 1, 3, 2, 5, 2, 1, 2, 1, 1, 2, (37 58, 17, 31, 13, 26, 41, 23, 37, 34, 29, (2)	2481 47097 93739 18762
1428	37; 1, 3, 1, (2) 59, 16, 47, (21)	90 3401
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1432	37; 1, 5, 3, 8, 10, 1, 2, 4, (9) 63, 12, 23, 9, 7, 49, 24, 17, (8)	46662 66363 17 65798 05797
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1435	37; 1, 7, 2, 3, (7) 66, 9, 31, 21, (10)	26373 9 99046
1436	37; 1, 8, 2, (18) 67, 8, 35, (4)	6840 2 59199
1437	37; 1, 9, 1, 5, 2, 2, 4, 18, 1, 2, 1, 1, 1, (24) 68, 7, 59, 12, 29, 28, 17, 4, 53, 21, 41, 28, 47, (3)	256 83205 64040 9735 93382 10399
1438	37; 1, 11, 1, 1, 1, 7, 1, 3, 3, 24, 1, (36) 69, 6, 47, 27, 46, 9, 53, 18, 23, 3, 71, (2)	42 08945 06064 1596 07281 27743
1439	37; 1, 14, 5, 2, 1, 5, 6, 1, 2, 1, 1, 2, 2, 1, 10, 7, 2, (37) 70, 5, 14, 25, 46, 13, 11, 49, 22, 37, 35, 26, 23, 50, 7, 10, 35, (2)	338 95537 37610 21521 12857 98517 00303 64960
1440	37; 1, (17) 71, (4)	19 721
1441	37; 1, 24, 3, 8, 9, 2, 1, 2, 2, 1, 3, 1, 3, 4, 1, 3, 1, 14, 2, 1, 1, 4, 2, (6) 72, 3, 24, 9, 8, 27, 40, 25, 24, 45, 17, 48, 19, 15, 51, 16, 57, 5, 29, 33, 40, 15, 32, (11)	221 54985 95953 31104 82700 8410 14472 84306 85240 54999
1442	37; 1, (36) 73, (2)	38 1443
1443	37; (1) (74)	1 38
1445*	38; (76) (1)	1 38
1446	38; (38) (2)	38 1445
1447	38; 25, 2, 1, 7, 1, 3, 1, 1, 2, 3, 1, 5, 12, 1, 1, (37) 3, 26, 47, 9, 54, 17, 39, 34, 27, 18, 51, 13, 6, 37, 39, (2)	3 42829 14389 10093 130 41033 17574 21848

1448	38 ; (19) (4)	19 723
1449	38 ; 15, 4, 1, 2, 4, (8) 5, 16, 45, 25, 17, (9)	72 84800 2773 01249
1450*	38 ; 12, 1, 2, (8, 8) 6, 49, 25, (9, 9)	1 01933 38 81493
1451	38 ; 10, 1, 6, 1, 2, 2, 3, 1, 1, 2, 2, 14, 1, 4, 1, 1, (37) 7, 61, 10, 49, 23, 29, 19, 38, 35, 25, 31, 5, 59, 14, 35, 41, (2)	85340 31566 20707 32 50782 78443 28530
1452	38 ; 9, 1, 1, (18) 8, 37, 39, (4)	6878 2 62087
1453*	38 ; 8, 2, 5, 2, 1, 1, 5, 1, 3, 6, 10, 1, 2, 1, 2, 1, 1, 3, 18, 1, 3, 1, 9, 33, 13, 28, 33, 41, 12, 51, 19, 12, 7, 52, 21, 44, 23, 36, 37, 21, 4, 57, 17, 36, 1, 6, 2, 1, 2, (25, 25) 39, 11, 27, 39, 28, (3, 3)	37 58165 73334 54563 77143 54805 1432 54652 50389 34442 96990 99982
1454	38 ; 7, 1, 1, 1, 1, 2, 2, 4, 15, (38) 10, 43, 31, 34, 37, 25, 29, 17, 5, (2)	96169 61884 36 67077 58095
1455	38 ; 6, 1, (11) 11, 61, (6)	623 23764
1456	38 ; 6, 2, 1, 7, 1, (3) 12, 25, 48, 9, 55, (16)	1 29855 49 54951
1457	38 ; 5, 1, 6, 9, 2, 1, 1, 10, 3, 4, (2) 13, 56, 11, 8, 29, 32, 43, 7, 23, 16, (31)	18 94953 10312 723 31628 36703
1458	38 ; 5, 2, 3, 1, 3, 1, 2, 1, 1, 7, 1, 10, (38) 14, 31, 18, 49, 17, 46, 23, 34, 41, 9, 62, 7, (2)	78 88890 25540 3012 27540 96401
1459	38 ; 5, 12, 1, 1, 7, 8, 2, 1, 4, 2, 2, 2, 1, 1, 1, 5, 4, 15, 25, 2, 1, 1, (37) 15, 6, 39, 37, 10, 9, 26, 45, 15, 29, 27, 25, 39, 30, 43, 13, 18, 5, 3, 30, 31, 45, (2)	25694 24820 98124 22872 52281 9 81439 56337 99403 45032 81010
1460	38 ; 4, 1, 3, 4, 1, 1, (18) 16, 49, 19, 16, 35, 41, (4)	6 25898 239 15529

1461	38; 4, 2, 14, 1, 5, 2, 3, 2, 1, 3, 3, 18, 1, 4, 6, 1, 2, 1, (24) 17, 33, 5, 61, 12, 31, 20, 25, 44, 19, 23, 4, 59, 15, 11, 51, 20, 55, (3)	10897 33506 65845 02228 4 16529 16197 97289 87575
1462	38; 4, (4) 18, (17)	72 2753
1463	38; (4) (19)	4 153
1464	38; 3, 1, 4, 2, 1, (5) 20, 49, 15, 25, 47, (12)	23729 9 07925
1465*	38; 3, 1, 1, 1, 2, 1, 1, 4, 4, 1, 7, 1, 2, (3, 3) 21, 40, 31, 39, 24, 35, 39, 16, 15, 56, 9, 49, 24, (21, 21)	2 14427 21285 82 07269 84932
1466*	38; 3, 2, 7, 4, 2, 1, (2, 2) 22, 31, 10, 17, 26, 41, (25, 25)	40 05185 1533 52043
1467	38; 3, 3, 6, 1, 1, 1, (37) 23, 22, 11, 46, 27, 49, (2)	16 73045 640 80026
1468	38; 3, 5, 1, 1, 3, 2, 25, 9, 1, 1, 5, 1, 6, 8, 2, 1, 2, 1, 1, (18) 24, 13, 39, 36, 19, 33, 3, 8, 39, 37, 12, 57, 11, 9, 27, 41, 24, 33, 43, (4)	18883 73036 64922 35216 7 23520 46281 34792 85247
1469	38; 3, 18, 1, (4) 25, 4, 61, (13)	19836 7 60265
1470	38; 2, 1, (14) 26, 49, (5)	138 5291
1471	38; 2, 1, 4, 1, 4, 3, 2, 4, 12, 1, 1, 3, 1, 2, 1, 6, 1, 14, 2, 8, 25, 27, 45, 14, 53, 15, 21, 30, 17, 6, 41, 35, 18, 47, 21, 51, 10, 63, 5, 35, 9, 3, 2, 4, 1, 1, 1, 1, 1, 10, 2, 1, (37) 34, 15, 42, 31, 37, 30, 45, 7, 25, 51, (2	1 01712 89163 97276 23871 56715 36737 39 01057 37347 28288 54875 60183 66160
1472	38; 2, 1, (2) 28, 41, (23)	30 1151
1473	38; 2, 1, 1, 1, 2, 1, 2, 2, 9, 5, 1, 3, 1, (24) 29, 37, 32, 39, 23, 43, 24, 31, 8, 13, 53, 16, 59, (3)	6 92736 14220 265 86992 93399

1474	38; 2, 1, 1, 4, 1, 7, 1, 2, 2, 4, 1, 2, 3, 1, 10, 5, (38) 30, 33, 41, 14, 57, 9, 50, 23, 30, 15, 46, 25, 18, 55, 7, 15, (2)	1 43151 08109 79476 54 95957 60507 29745
1475	38; 2, 2, 6, 1, 1, (2) 31, 29, 11, 41, 34, (25)	14628 5 61799
1476	38; 2, 2, 1, 1, 2, 1, 3, (8) 32, 25, 36, 37, 23, 45, 20, (9)	2 18560 83 96801
1477	38; 2, 3, 6, 8, 2, 1, 1, 1, 1, 1, 5, 1, 3, 1, 2, 18, 1, 6, 25, 2, (10) 33, 21, 12, 9, 28, 37, 33, 36, 31, 43, 12, 53, 17, 44, 27, 4, 63, 11, 3, 36, (7)	2 61633 72121 47062 22240 100 55043 78017 41504 36351
1478	38; 2, 4, (38) 34, 17, (2)	3114 1 19717
1479	38; 2, 5, 2, 2, 1, 1, 1, (1) 35, 13, 30, 25, 38, 33, 35, (34)	1 14525 44 04376
1480	38; 2, 8, (19) 36, 9, (4)	5559 2 13859
1481*	38; 2, 14, 1, 8, 1, 2, 5, 1, 1, 2, 1, 4, 10, 1, 3, 1, 1, (1, 1) 37, 5, 65, 8, 49, 25, 13, 40, 35, 23, 47, 16, 7, 56, 17, 41, 32, (35, 35)	1 01945 97513 61405 39 23264 72655 17468
1482	38; (2) (38)	2 77
1483	38; 1, 1, 25, 5, 1, 7, 1, 2, 1, 1, 1, 1, 2, 4, 6, 1, 3, 2, 2, 1, 1, 12, 3, 1, (37) 39, 38, 3, 13, 58, 9, 51, 22, 39, 33, 34, 37, 27, 17, 11, 53, 18, 29, 26, 33, 43, 6, 19, 57, (2)	41 20928 70570 44632 38045 1586 95889 00942 30191 81226
1484	38; 1, 1, (10) 40, 37, (7)	44 1695
1485	38; 1, 1, (6) 41, 36, (11)	28 1079
1486	38; 1, 1, 4, 1, 1, 1, 3, (38) 42, 35, 15, 43, 30, 41, 21, (2)	4 92228 189 74735
1487	38; 1, 1, 3, 1, 1, 3, 1, (37) [illegible]	2 05495 [illegible]

1488	38; 1, 1, 2, 1, (5) 44, 33, 23, 49, (12)	315 12151
1489*	38; 1, 1, 2, 2, 1, 4, 2, 3, 1, (1, 1) 45, 32, 27, 24, 47, 15, 31, 19, 40, (33, 33)	25 78145 994 84332
1490*	38; 1, (1, 1) 46, (31, 31)	5 193
1491	38; 1, 1, 1, 1, 2, 2, (1) 47, 30, 35, 37, 26, 25, (42)	1767 68230
1492	38; 1, 1, 1, 2, 10, 1, 1, 1, (18) 48, 29, 39, 28, 7, 48, 27, 49, (4)	13 56270 523 87849
1493*	38; 1, 1, 1, 3, 2, 2, 18, 1, (10, 10) 49, 28, 43, 19, 28, 31, 4, 67, (7, 7)	1694 41225 65471 00182
1494	38; 1, 1, 1, 7, 15, 5, (38) 50, 27, 47, 10, 5, 25, (2)	440 05214 17009 02565
1495	38; 1, (1) 51, (26)	3 116
1496	38; 1, 2, (9) 52, 25, (8)	87 3365
1497	38; 1, 2, 4, 4, 1, 1, 1, 1, 6, 2, 2, 1, 8, 1, (24) 53, 24, 17, 16, 41, 33, 32, 43, 11, 31, 23, 51, 8, 67, (3)	58 19614 30932 2251 67187 51127
1498	38; 1, 2, 2, 1, 1, 1, 3, 1, 12, 8, 1, 1, (10) 54, 23, 26, 39, 31, 42, 17, 57, 6, 9, 38, 39, (7)	83118 18384 32 17006 59967
1499	38; 1, 2, 1, 1, 7, 5, 1, 4, 1, 2, 3, 1, 2, 1, 1, 2, 10, 1, 2, 15, 6, 1, (37) 55, 22, 35, 41, 10, 13, 55, 14, 47, 25, 19, 46, 23, 38, 35, 29, 7, 49, 26, 5, 11, 65, (2)	77552 05839 43067 80299 30 02576 94656 26953 60610
1500	38; 1, 2, 1, 2, 2, 1, 6, 2, 1, (18) 56, 21, 44, 25, 24, 49, 11, 25, 51, (4)	118 11844 4574 70751

End of Table.

In connexion with the subject we have a paper, 'A Table of the Square Roots of Prime Numbers of the form $4m+1$ less than 10000 expanded as Periodic Continued Fractions,' by C. A. Roberts, with Introduction and Explanation by Artemas Martin, the 'Mathematical Magazine,' vol. ii. (No. 7, for October 1892), pp. 105–120. This extends, in fact, to numbers up to 10501, but only the denominators of the continued fractions (that is, the first lines of Degen's and the present table) are given: thus the entry for 1009 is 31; 1, (3, 3).

The paper just referred to notices errors in Degen's tables for the numbers 853 and 929. For 853 the first line should be

29, 4, 1, 5, 1, 2, 4, 1, 1, 15, 19, (2, 2)

(15 instead of Degen's 14). For 929 the first and second lines should be

30, 2, 11, 1, 2, 3, 2, 7, 5, (2, 2)
1, 29, 5, 40, 19, 16, 25, 8, 11, (23, 23)

The values of x, y in Table I. and those in Table II. (for the solution of $y^2=ax^2-1$) are correct for each of the numbers 853 and 929.

On the Establishment of a National Physical Laboratory.—Report of the Committee, consisting of Professor OLIVER J. LODGE (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, Lord RAYLEIGH, Sir H. E. ROSCOE, Professors J. J. THOMSON, A. W. RÜCKER, R. B. CLIFTON, G. F. FITZGERALD, G. CAREY FOSTER, J. VIRIAMU JONES, A. SCHUSTER, *and* W. E. AYRTON.

THE Committee hoped to have been able to present a report dealing with the work done at the Reichsanstalt in Berlin and the Bureau International at Sèvres. They have not, however, been able to prepare this report in time for the meeting, and they desire to be reappointed to continue their investigations.

The Best Means of Comparing and Reducing Magnetic Observations.—Interim Report of the Committee, consisting of Professor W. GRYLLS ADAMS (*Chairman and Secretary*), Lord KELVIN, Professors G. H. DARWIN *and* G. CHRYSTAL, Mr. C. H. CARPMAEL, Professor A. SCHUSTER, Mr. G. M. WHIPPLE, Captain CREAK, THE ASTRONOMER ROYAL, Mr. WILLIAM ELLIS, *and* Professor A. W. RÜCKER.

THE Committee have considered and reported to the Admiralty on plans, submitted to them by Mr. Gill, for a Magnetic Observatory at the Cape of Good Hope. In conjunction with Mr. Gill, they have drawn up a scheme embodying their recommendations as to its establishment and maintenance, which has been laid before, and is under the consideration of, the Admiralty.

The Committee desire to be reappointed, with the addition of Mr. Charles Chree in the place of the late Mr. G. M. Whipple.

On Electro-optics.—Report of the Committee, consisting of Dr. JOHN KERR (*Chairman*), Mr. R. T. GLAZEBROOK (*Secretary*), Lord KELVIN, *and* Professor A. W. RÜCKER.

THE Committee report that Dr. Kerr's experiments have been continued, and that he hopes shortly to have further results ready for publication.

Magnetic Work at the Falmouth Observatory.—Report of the Committee, consisting of Mr. HOWARD FOX, Professor A. W. RÜCKER, *and* Professor W. G. ADAMS.

Magnetical Observations.

[Made at the Falmouth Observatory, latitude 50° 9′ 0″ N. and longitude 5° 4′ 35″ W., height 167 feet above mean sea level, for the year 1892, by Edward Kitto, Superintendent.]

THE results in the following tables, Nos. 1, 2, 3, 4, are deduced from the magnetograph curves which have been standardised by observations of deflection and vibration. These were made with the collimator magnet marked 66A, and the declinometer magnet marked 66C in the unifilar magnetometer by Elliott Bros., of London. Table No. 5 is deduced from these observations.

The inclination was observed with the inclinometer by Dover, of Charlton, Kent, No. 86, and needles 1 and 2, which are 3½ inches in length, the results of which appear in Table No. 6.

The declination and horizontal force values given in Tables 1 to 4 are prepared in accordance with the suggestions made in the fifth report of the Committee of the British Association on Comparing and Reducing Magnetic Observations.

The following is a list of the days during the year 1892 which were selected by the Astronomer Royal as suitable for the determination of the magnetic diurnal variations, and which have been employed in the preparation of the magnetic tables :—

January	2, 9, 20, 22, 30.
February	3, 8, 17, 18, 22.
March	10, 14, 17, 18, 23.
April	5, 6, 17, 20, 22.
May	12, 13, 15, 23, 26.
June	8, 9, 12, 14, 15.
July	5, 6, 8, 20, 23.
August	11, 14, 15, 19, 30.
September	4, 5, 9, 12, 25.
October	9, 17, 23, 26, 28.
November	8, 11, 12, 16, 27.
December	3, 9, 18, 26, 27.

Table I.—*Hourly Means of Declination at the Falmouth*
Five selected quiet Days in each Month

Hours . . .	1	2	3	4	5	6	7	8	9	10	11	Noon
						Winter.						
1892 Months	′	′	′	′	′	′	′	′	′	′	′	′
January . .	15·5	15·3	15·1	15·0	15·2	15·4	15·3	14·9	15·0	16·4	17·9	20·7
February . .	13·8	13·1	13·2	14·2	13·8	15·0	14·9	15·2	15·2	15·7	17·6	20·0
March . .	14·5	14·7	14·8	14·9	15·3	14·4	13·4	12·3	12·8	13·9	16·5	20·2
October . .	10·5	10·6	10·5	10·6	10·9	10·6	10·4	9·1	8·4	9·2	11·9	15·5
November .	9·8	10·1	9·9	10·2	9·7	9·7	9·3	9·4	8·7	8·9	10·1	12·4
December .	9·4	9·9	9·7	10·0	9·8	9·3	9·2	9·2	9·4	10·6	12·2	13·6
Means . .	12·3	12·3	12·2	12·1	12·5	12·4	12·1	11·7	11·6	12·5	14·4	17·1
						Summer.						
1892 Months	′	′	′	′	′	′	′	′	′	′	′	′
April . .	13·7	13·3	13·2	12·9	12·5	12·2	10·7	9·6	9·4	11·4	14·4	17·9
May . . .	12·8	12·9	12·4	11·7	10·3	8·9	7·7	7·7	8·8	11·5	14·9	18·4
June . . .	12·1	12·1	12·1	11·2	9·5	7·4	6·9	7·0	8·2	11·0	13·7	17·4
July . . .	11·3	10·7	10·4	9·9	8·2	6·4	5·8	5·6	6·4	8·6	11·4	14·8
August . .	10·0	10·4	9·6	9·3	8·5	7·1	5·9	5·8	7·0	10·0	13·7	17·1
September .	10·2	9·9	9·2	9·1	8·6	7·9	7·1	6·9	8·2	11·6	14·6	17·8
Means . .	11·7	11·6	11·2	11·4	9·6	8·3	7·4	7·1	8·0	10·7	13·8	17·2

Table II.—*Solar Diurnal Range of the Falmouth*

Hours	1	2	3	4	5	6	7	8	9	10	11	Noon
						Summer Mean.						
	′ −0·7	′ −0·8	′ −1·2	′ −1·0	′ −2·8	′ −4·1	′ −5·0	′ −5·3	′ −4·4	′ −1·7	′ +1·4	′ +4·8
						Winter Mean.						
	′ −1·4	′ −1·4	′ −1·5	′ −1·6	′ −1·2	′ −1·3	′ −1·6	′ −2·0	′ −2·1	′ −1·2	′ +0·7	′ +3·4
						Annual Mean.						
	′ −1·1	′ −1·1	′ −1·4	′ −1·3	′ −2·0	′ −2·7	′ −3·3	′ −3·7	′ −3·3	′ −1·5	′ +1·1	′ +4·1

Note.—When the sign is + the magnet

Observatory, determined from the Magnetograph Curves on during the year 1892. (19° + West.)

1	2	3	4	5	6	7	8	9	10	11	Mid.
					Winter.						
′	′	′	′	′	′	′	′	′	′	′	′
21·7	21·2	19·9	18·8	18·0	17·3	16·8	15·8	15·5	15·1	15·0	15·2
20·6	20·8	20·1	18·1	16·7	16·8	16·3	15·4	14·5	14·2	13·8	13·6
22·0	21·8	20·7	19·0	17·1	16·1	15·3	15·4	14·8	14·3	15·2	15·4
17·6	18·7	17·5	15·6	14·1	12·7	11·9	11·6	11·3	10·8	10·5	10·1
13·4	13·9	13·1	12·7	11·9	11·1	10·7	10·4	9·8	9·7	9·5	9·7
14·6	13·7	13·3	12·0	11·7	11·8	10·9	10·0	9·5	8·7	8·5	8·9
18·3	18·4	17·5	16·0	14·9	14·3	13·7	13·1	12·6	12·1	12·1	12·2
					Summer.						
′	′	′	′	′	′	′	′	′	′	′	′
19·9	20·1	18·8	17·4	15·8	15·2	15·1	15·0	14·6	14·8	14·6	14·3
20·1	19·5	18·0	16·2	14·4	12·9	12·3	12·6	12·8	13·2	13·0	12·9
19·7	19·9	18·1	16·8	15·3	14·0	13·0	12·7	12·6	12·9	12·6	12·5
17·3	18·5	17·6	15·3	13·6	12·1	11·5	11·3	11·6	11·8	11·6	11·6
19·2	18·5	16·4	13·6	11·5	10·5	10·4	10·3	10·4	10·6	10·1	9·4
18·6	17·9	16·0	13·7	11·8	11·0	10·9	10·6	10·1	10·5	10·5	10·0
19·1	19·1	17·5	15·5	13·7	12·6	12·2	12·1	12·0	12·3	12·1	11·8

Declination as derived from Table I.

1	2	3	4	5	6	7	8	9	10	11	Mid.
					Summer Mean.						
′	′	′	′	′	′	′	′	′	′	′	′
+6·7	+6·7	+5·1	+3·1	+1·3	+0·2	−0·2	−0·3	−0·4	−0·1	−0·3	−0·6
					Winter Mean.						
′	′	′	′	′	′	′	′	′	′	′	′
+4·6	+4·7	+3·8	+2·3	+1·2	+0·6	0·0	−0·6	−1·1	−1·6	−1·6	−1·5
					Annual Mean.						
′	′	′	′	′	′	′	′	′	′	′	′
+5·7	+5·7	+4·5	+2·7	+1·3	+0·4	−0·1	−0·5	−0·8	−0·9	−1·0	−1·1

points to the west of its mean position.

TABLE III.—*Hourly Means of the Horizontal Force*[1] *at Falmouth (corrected for Temperature) on Five selected quiet Days in each*

Hours . . .	1	2	3	4	5	6	7	8	9	10	11	Noon
Winter.												
1892 Months												
January . .	444	446	444	448	450	450	451	447	439	426	420	422
February . .	410	408	404	405	407	406	413	413	407	397	385	385
March . .	430	432	433	434	436	438	433	427	417	407	402	401
October . .	452	454	455	455	456	457	457	449	435	425	422	420
November .	460	460	463	464	465	467	466	462	453	447	445	445
December .	452	453	453	456	457	460	461	457	452	444	442	440
Means .	441	442	442	444	445	446	447	443	434	431	419	419
Summer.												
1892 Months												
April . .	462	460	460	460	459	458	455	450	438	427	425	430
May . . .	446	443	443	440	443	438	429	417	408	407	405	413
June . .	456	455	454	454	454	448	438	429	421	420	429	437
July . . .	453	449	448	447	445	440	435	429	419	412	409	410
August . .	456	454	455	453	452	451	444	432	417	411	411	420
September .	460	457	458	458	457	454	446	436	427	423	425	439
Means .	456	453	453	452	452	448	441	432	422	417	417	425

TABLE IV.—*Diurnal Range of the Falmouth Horizontal*

Hours	1	2	3	4	5	6	7	8	9	10	11	Noon
Summer Mean.												
	+·00009	+·00006	+·00006	+·00005	+·00005	+·00001	—·00006	—·00015	—·00025	—·00030	—·00030	—·00022
Winter Mean.												
	+·00001	+·00002	+·00002	+·00004	+·00005	+·00006	+·00007	+·00003	—·00006	—·00009	—·00021	—·00021
Annual Mean.												
	+·00005	+·00004	+·00004	+·00004	+·00005	+·00004	+·00001	—·00006	—·00015	—·00020	—·C0026	—·00022

[1] Approximate values.

NOTE.—When the sign is + the

Observatory as determined from the Magnetograph Curves.
Month during the year 1892. 0·18000 + (C.G.S. units).

1	2	3	4	5	6	7	8	9	10	11	Mid.
					Winter.						
429	435	438	441	442	446	448	449	448	448	450	451
390	396	402	407	410	420	415	421	421	414	417	419
407	418	429	429	427	431	444	444	439	440	443	443
431	438	440	444	447	451	454	458	458	459	459	458
446	453	459	462	465	465	466	467	469	469	467	470
443	446	448	451	457	458	459	460	456	454	454	452
424	431	436	439	441	445	448	450	449	447	448	449
					Summer.						
433	444	453	460	459	464	465	465	464	467	463	462
421	430	440	447	453	454	457	453	456	454	452	452
442	449	456	454	458	462	466	467	466	466	462	461
418	429	440	447	452	458	461	460	460	456	455	454
431	439	449	456	459	462	464	468	468	466	467	463
450	457	457	455	455	459	465	465	465	462	463	462
433	441	449	453	456	460	463	463	463	462	460	459

Force as deduced from Table III. (C.G.S. units.)

1	2	3	4	5	6	7	8	9	10	11	Mid.
					Summer Mean.						
—·00014	—·00006	+·00002	+·00006	+·00009	+·00013	+·00016	+·00016	+·00016	+·00015	+·00013	+·00012
					Winter Mean.						
—·00016	—·00009	—·00004	—·00001	+·00001	+·00005	+·00008	+·00010	+·00009	+·00007	+·00008	+·00009
					Annual Mean.						
—·00015	—·00008	+·00001	+·00003	+·00005	+·00009	+·00012	+·00013	+·00013	+·00011	+·00011	+·00011

reading is above the mean.

TABLE V.—*Magnetic Intensity. Falmouth Observatory*, 1892.

1892	C.G.S. Measure	
	X or Horizontal Force	Y or Vertical Force
January	0·18426	0·43691
February	0·18405	0·43624
March	0·18444	0·43734
April	0·18435	0·43727
May	0·18448	0·43673
June	0·18465	0·43694
July	0·18453	0·43706
August	0·18447	0·43702
September	0·18424	0·43683
October	0·18437	0·43689
November	0·18450	0·43691
December	0·18439	0·43619
Means	0·18439	0·43686

TABLE VI.—*Observations of Magnetic Inclination. Falmouth Observatory*, 1892.

Month	Mean at 10 A.M.	Month	Mean at 10 A.M.
January 29	67° 9′·4	July 28	67° 7′·8
„ 30	67 6·7	„ 29	67 6·8
		„ 30	67 5·1
	67 8·0		67 6·6
February 25	67 7·1	August 27	67 6·1
„ 27	67 7·8	„ 31	67 7·7
	67 7·5		67 6·9
March 28	67 7·9	September 28	67 7·3
„ 29	67 9·0	„ 29	67 8·6
„ 30	67 7·0		
	67 8·0		67 7·9
April 27	67 8·4	October 27	67 7·7
„ 29	67 8·0	„ 28	67 6·7
„ 30	67 8·7	„ 29	67 7·1
	67 8·4		67 7·2
May 27	67 6·2	November 25	67 6·6
„ 28	67 5·8	„ 26	67 6·2
	67 6·0		67 6·4
June 28	67 7·4	December 21	67 6·1
„ 29	67 7·3	„ 22	67 4·7
„ 30	67 5·7	„ 23	67 4·6
	67 6·8		67 5·1

Experiments for Improving the Construction of Practical Standards for Electrical Measurements.—Report of the Committee, consisting of Professor CAREY FOSTER (*Chairman*), Lord KELVIN, Professors AYRTON, J. PERRY, W. G. ADAMS, Lord RAYLEIGH, *and* O. J. LODGE, Drs. JOHN HOPKINSON *and* A. MUIRHEAD, Messrs. W. H. PREECE *and* HERBERT TAYLOR, Professor J. D. EVERETT, Professor A. SCHUSTER, Dr. J. A. FLEMING, Professors G. F. FITZGERALD, G. CHRYSTAL, *and* J. J. THOMSON, Messrs. R. T. GLAZEBROOK (*Secretary*), W. N. SHAW, *and* T. C. FITZPATRICK, Dr. J. T. BOTTOMLEY, Professor J. VIRIAMU JONES, Dr. G. JOHNSTONE STONEY, Professor S. P. THOMPSON, *and* Mr. G. FORBES.

THE work of testing resistance coils at the Cavendish Laboratory has been continued. A table of the coils tested is given. They have all been 'ohms,' as defined by the resolution of the Committee given in their last report, and since adopted by the Board of Trade Committee on electrical standards in the following form:—

The resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass, of a constant cross-sectional area, and of a length of 106·3 centimetres, may be taken as 1 ohm. The relation between the B.A. unit and the ohm is the following:—

1 B.A.U.=·9866 ohm.

TABLE I.

Ohms.

No. of Coil		Value in Ohms	Temperature
Nalder, 3717 . . .	No. 361	1·00025	17°·7
Nalder, 3874 . . .	No. 362	9·9926	14°·9
Nalder, 3059 [1] . . .	No. 326	1·00000	16°·5
Nalder, 3633 . . .	No. 363	100·000	17°·2
Nalder, 3637 . . .	No. 364	100·000	17°·05
Nalder, 3635 . . .	No. 365	1000·00	17°·3
Nalder, 3872 . . .	No. 366	9·9947	14°·9
Nalder, 3873 . . .	No. 367	9·9919	14°·8
Nalder, 4085 . . .	No. 368	·99889	14°·8

[1] This coil had been tested before.

TABLE I.

OHMS—*continued.*

No. of Coil		Value in Ohms	Temperature
Nalder, 3263 . . .	No. 369	·99895	14°·2
Warden, 1866 . . .	No. 370	1·00080	14°·5
Warden, 1918 . . .	No. 371	1·00041	14°·3
Nalder, 3715 . . .	No. 372	·99944	13°·5
Nalder, 3719 . . .	No. 373	·99907	13°·3
Nalder, 3720 . . .	No. 374	·99898	13°·3
Nalder, 3633 . . .	No. 375	9·9910	15°·3
Nalder, 3876 . . .	No. 376	·99932	15°·2
Nalder, 3981 . . .	No. 377	10·0001	15°·7
Nalder, 4086 . . .	No. 378	·99978	15°·9
Elliott, 303 . . .	No. 379	1·00054	18°·2
Elliott, 304 . . .	No. 380	1·00052	18°·1

The resolutions adopted by the Committee at Edinburgh were communicated to the Electrical Standards Committee of the Board of Trade. After consideration the Board of Trade Committee drew up an amended report, in harmony with the Edinburgh resolutions, for presentation to the President (see Appendix I.).

The resolutions were accepted at Edinburgh by Dr. von Helmholtz on behalf of Germany, while in France an official committee decided last June to adhere to the propositions of the Board of Trade. Austria and Italy are connected by treaty with Germany for telegraph purposes, and in consequence adopt the same units.

The Committee have learnt with pleasure from Mr. W. H. Preece, one of the English delegates to the International Congress of Electricians at Chicago, that the Congress has accepted a series of resolutions defining the fundamental units practically identical with the Edinburgh resolutions.

Thus these resolutions have now been accepted as a basis for legislation throughout the British Empire, the whole of Western Europe, and the United States of America.

The Committee are also informed that the Chicago Congress have adopted the name 'Henry' for the unit of self-induction; while looking with favour on this suggestion, they think it desirable to postpone definite action until the official report of the Congress has been received.

In March last M. Mascart wrote to the Secretary asking the opinion of the Committee as to a name for the standard of resistance defined at Edinburgh. A circular letter was issued inviting members of the Committee to express their views on four names which had been suggested, viz.: 'International,' 'Normal,' 'Etalion,' or 'Ohm de 1893.' After receiving replies to the circular from twelve members of the Committee, the Secretary wrote to Professor Mascart to the effect that the number

of members who expressed a preference for the name 'International' was greater than the number declaring in favour of any other name, but that he thought that the Committee would accept whichever of the first three suggestions commended itself to the French Committee appointed to deal with the matter.

During the year Dr. Muirhead has remeasured his standard condenser. He now finds as the capacity of a condenser constructed twenty-three years ago to represent ·1 microfarad (B.A.U.) the value ·09998 microfarad.

Tests have been made during the year on the 1-ohm and 10-ohm standards of the Association. These are still being continued. The 100-ohm and 1000-ohm standards have now been delivered, and the tests will be shortly proceeded with. Some experiments were made as to the amount of heating in the coils produced by the current used for testing. These are detailed in Appendix II. Further valuable information on this point is contained in Mr. Griffiths' paper on 'The Value of the Mechanical Equivalent of Heat.'[1]

The Committee think it desirable that they should be in a position to complete the set of resistance standards of the Association, and recommend, therefore, that they be reappointed, with a grant of 25*l.*, that Professor G. Carey Foster be Chairman, and Mr. R. T. Glazebrook Secretary.

APPENDIX I.

Supplementary Report of the Electrical Standards Committee of the Board of Trade.

To the Right Hon. A. J. Mundella, M.P.,
President of the Board of Trade.

Subsequently to the presentation of our former report to Sir Michael Hicks-Beach, in July 1891, we were informed that it was probable that the German Government would shortly take steps to establish legal standards for use in connection with electrical supply, and that, with a view to secure complete agreement between the proposed standards in Germany and England, the Director of the Physico-Technical Imperial Institute at Berlin, Professor von Helmholtz, with certain of his assistants, proposed to visit England for the purpose of making exact comparisons between the units in use in the two countries, and of attending the meeting of the British Association which was to take place in August in Edinburgh.

Having regard to the importance of this communication it appeared desirable that the Board of Trade should postpone the action recommended in our previous report until after Professor Helmholtz's visit.

That visit took place early in August, and there was a very full discussion of the whole subject at the meeting of the British Association in Edinburgh, at which several of our number were present. The meeting was also attended by Dr. Guillaume, of the *Bureau International des Poids et Mesures*, and Professor Carhart, of the University of Michigan,

[1] *Phil. Trans.*, 1893.

U.S.A., who were well qualified by their scientific attainments to represent the opinion of their respective countries.

It appeared from the discussion that a few comparatively slight modifications of the resolutions included in our previous report would tend to secure international agreement.

An extract from the report of the Electrical Standards Committee of the British Association embodying the results of this discussion was communicated to us by the Secretary, and will be found in the appendix to this report.

Having carefully reconsidered the whole question in view of this communication, and having received the report of the sub-committee mentioned in resolution 14 of our previous report, we now desire, for the resolutions contained in that report, to substitute the following:—

Resolutions.

1. That it is desirable that new denominations of standards for the measurement of electricity should be made and approved by her Majesty in Council as Board of Trade standards.

2. That the magnitudes of these standards should be determined on the electro-magnetic system of measurement with reference to the centimetre as unit of length, the gramme as unit of mass, and the second as unit of time, and that by the terms centimetre and gramme are meant the standards of those denominations deposited with the Board of Trade.

3. That the standard of electrical resistance should be denominated the ohm, and should have the value 1,000,000,000 in terms of the centimetre and second.

4. That the resistance offered to an unvarying electric current by a column of mercury at the temperature of melting ice 14·4521 grammes in mass of a constant cross-sectional area, and of a length of 106·3 centimetres, may be adopted as 1 ohm.

5. That a material standard, constructed in solid metal, should be adopted as the standard ohm, and should from time to time be verified by comparison with a column of mercury of known dimensions.

6. That, for the purpose of replacing the standard, if lost, destroyed, or damaged, and for ordinary use, a limited number of copies should be constructed, which should be periodically compared with the standard ohm.

7. That resistances constructed in solid metal should be adopted as Board of Trade standards for multiples and sub-multiples of the ohm.

8. That the value of the standard of resistance constructed by a committee of the British Association for the Advancement of Science in the years 1863 and 1864, and known as the British Association unit, may be taken as ·9866 of the ohm.

9. That the standard of electrical current should be denominated the ampere, and should have the value one-tenth (0·1) in terms of the centimetre, gramme, and second.

10. That an unvarying current which, when passed through a solution of nitrate of silver in water, in accordance with the specification attached to this report, deposits silver at the rate of 0·001118 of a gramme per second may be taken as a current of 1 ampere.

11. That an alternating current of 1 ampere shall mean a current

such that the square root of the time average of the square of its strength at each instant in amperes is unity.

12. That instruments constructed on the principle of the balance, in which, by the proper disposition of the conductors, forces of attraction and repulsion are produced, which depend upon the amount of current passing, and are balanced by known weights, should be adopted as the Board of Trade standards for the measurement of current, whether unvarying or alternating.

13. That the standard of electrical pressure should be denominated the volt, being the pressure which, if steadily applied to a conductor whose resistance is 1 ohm, will produce a current of 1 ampere.

14. That the electrical pressure at a temperature of 15° Centigrade between the poles or electrodes of the voltaic cell known as Clark's cell, prepared in accordance with the specification attached to this report, may be taken as not differing from a pressure of 1·434 volt by more than one part in one thousand.

15. That an alternating pressure of 1 volt shall mean a pressure such that the square root of the time-average of the square of its value at each instant in volts is unity.

16. That instruments constructed on the principle of Lord Kelvin's quadrant electrometer used idiostatically, and, for high pressures, instruments on the principle of the balance, electrostatic forces being balanced against a known weight, should be adopted as Board of Trade standards for the measurement of pressure, whether unvarying or alternating.

(Signed) COURTENAY BOYLE. KELVIN.
P. CARDEW. W. H. PREECE.
RAYLEIGH. G. CAREY FOSTER.
R. T. GLAZEBROOK. J. HOPKINSON.
W. E. AYRTON.

T. W. P. BLOMEFIELD, *Secretary*.

November 29, 1892.

SPECIFICATION REFERRED TO IN RESOLUTION 10.

In the following specification the term silver voltameter means the arrangement of apparatus by means of which an electric current is passed through a solution of nitrate of silver in water. The silver voltameter measures the total electrical quantity which has passed during the time of the experiment, and by noting this time the time-average of the current, or if the current has been kept constant the current itself, can be deduced.

In employing the silver voltameter to measure currents of about 1 ampere the following arrangements should be adopted. The kathode on which the silver is to be deposited should take the form of a platinum bowl not less than 10 centimetres in diameter, and from 4 to 5 centimetres in depth.

The anode should be a plate of pure silver some 30 square centimetres in area and 2 or 3 millimetres in thickness.

This is supported horizontally in the liquid near the top of the solution by a platinum wire passed through holes in the plate at opposite corners. To prevent the disintegrated silver which is formed on the

anode from falling on to the kathode the anode should be wrapped round with pure filter-paper, secured at the back with sealing-wax.

The liquid should consist of a neutral solution of pure silver nitrate, containing about fifteen parts by weight of the nitrate to eighty-five parts of water.

The resistance of the voltameter changes somewhat as the current passes. To prevent these changes having too great an effect on the current some resistance besides that of the voltameter should be inserted in the circuit. The total metallic resistance of the circuit should not be less than 10 ohms.

Method of making a Measurement.

The platinum bowl is washed with nitric acid and distilled water, dried by heat, and then left to cool in a desiccator. When thoroughly dry it is weighed carefully.

It is nearly filled with the solution, and connected to the rest of the circuit by being placed on a clean copper support to which a binding screw is attached. This copper support must be insulated.

The anode is then immersed in the solution, so as to be well covered by it and supported in that position; the connections to the rest of the circuit are made.

Contact is made at the key, noting the time of contact. The current is allowed to pass for not less than half an hour, and the time at which contact is broken is observed. Care must be taken that the clock used is keeping correct time during this interval.

The solution is now removed from the bowl and the deposit is washed with distilled water and left to soak for at least six hours. It is then rinsed successively with distilled water and absolute alcohol and dried in a hot-air bath at a temperature of about 160° C. After cooling in a desiccator it is weighed again. The gain in weight gives the silver deposited.

To find the current in amperes this weight, expressed in grammes, must be divided by the number of seconds during which the current has been passed and by ·001118.

The result will be the time-average of the current, if during the interval the current has varied.

In determining by this method the constant of an instrument the current should be kept as nearly constant as possible, and the readings of the instrument taken at frequent observed intervals of time. These observations give a curve from which the reading corresponding to the mean current (time-average of the current) can be found. The current, as calculated by the voltameter, corresponds to this reading.

Specification referred to in Resolution 14.

Definition of the Cell.

The cell consists of zinc and mercury in a saturated solution of zinc sulphate and mercurous sulphate in water, prepared with mercurous sulphate in excess, and is conveniently contained in a cylindrical glass vessel.

Preparation of the Materials.

1. *The Mercury.*—To secure purity it should be first treated with acid in the usual manner and subsequently distilled in vacuo.

2. *The Zinc.*—Take a portion of a rod of pure redistilled zinc, solder to one end a piece of copper wire, clean the whole with glass-paper, carefully removing any loose pieces of the zinc. Just before making up the cell dip the zinc into dilute sulphuric acid, wash with distilled water, and dry with a clean cloth or filter-paper.

3. *The Zinc Sulphate Solution.*—Prepare a saturated solution of pure ('pure recrystallised') zinc sulphate by mixing in a flask distilled water with nearly twice its weight of crystals of pure zinc sulphate, and adding zinc oxide in the proportion of about 2 per cent. by weight of the zinc sulphate crystals to neutralise any free acid.[1] The crystals should be dissolved with the aid of gentle heat, but the temperature to which the solution is raised should not exceed 30° C. Mercurous sulphate treated as described in 4 should be added in the proportion of about 12 per cent. by weight of the zinc sulphate crystals, and the solution filtered, while still warm, into a stock bottle. Crystals should form as it cools.

4. *The Mercurous Sulphate.*—Take mercurous sulphate, purchased as pure, and wash it thoroughly with cold distilled water by agitation in a bottle; drain off the water and repeat the process at least twice.[1] After the last washing drain off as much of the water as possible.

Mix the washed mercurous sulphate with the zinc sulphate solution, adding sufficient crystals of zinc sulphate from the stock bottle to ensure saturation, and a small quantity of pure mercury. Shake these up well together to form a paste of the consistence of cream. Heat the paste, but not above a temperature of 30° C. Keep the paste for an hour at this temperature, agitating it from time to time, then allow it to cool; continue to shake it occasionally while it is cooling. Crystals of zinc sulphate should then be distinctly visible, and should be distributed throughout the mass; if this is not the case add more crystals from the stock bottle, and repeat the whole process.

This method ensures the formation of a saturated solution of zinc and mercurous sulphates in water.

Contact is made with the mercury by means of a platinum wire about No. 22 gauge. This is protected from contact with the other materials of the cell by being sealed into a glass tube. The ends of the wire project from the ends of the tube; one end forms the terminal, the other end and a portion of the glass tube dip into the mercury.

To set up the Cell.

The cell may conveniently be set up in a small test tube of about 2 centimetres diameter and 6 or 7 centimetres deep. Place the mercury in the bottom of this tube, filling it to a depth of, say, 1·5 centimetre. Cut a cork about ·5 centimetre thick to fit the tube; at one side of the cork bore a hole through which the zinc rod can pass tightly; at the other side bore another hole for the glass tube which covers the platinum wire; at the edge of the cork cut a nick through which the air can pass

[1] See Notes.

when the cork is pushed into the tube. Wash the cork thoroughly with warm water, and leave it to soak in water for some hours before use. Pass the zinc rod about 1 centimetre through the cork.

Clean the glass tube and platinum wire carefully, then heat the exposed end of the platinum red-hot, and insert it in the mercury in the test tube, taking care that the whole of the exposed platinum is covered.

Shake up the paste and introduce it without contact with the upper part of the walls of the test tube, filling the tube above the mercury to a depth of rather more than 2 centimetres.

Then insert the cork and zinc rod, passing the glass tube through the hole prepared for it. Push the cork gently down until its lower surface is nearly in contact with the liquid. The air will thus be nearly all expelled, and the cell should be left in this condition for at least twenty-four hours before sealing, which should be done as follows:—

Melt some marine glue until it is fluid enough to pour by its own weight, and pour it into the test tube above the cork, using sufficient to cover completely the zinc and soldering. The glass tube should project above the top of the marine glue.

The cell thus set up may be mounted in any desirable manner. It is convenient to arrange the mounting so that the cell may be immersed in a water-bath up to the level of, say, the upper surface of the cork. Its temperature can then be determined more accurately than is possible when the cell is in air.

In using the cell sudden variations of temperature should as far as possible be avoided.

Notes.

The Zinc Sulphate Solution.—The object to be attained is the preparation of a neutral solution of pure zinc sulphate saturated with $ZnSO_4,7H_2O$.

At temperatures above 30° C. the zinc sulphate may crystallise out in another form; to avoid this 30° C. should be the upper limit of temperature. At this temperature water will dissolve about 1·9 time its weight of the crystals. If any of the crystals put in remain undissolved they will be removed by the filtration.

The amount of zinc oxide required depends on the acidity of the solution, but 2 per cent. will, in all cases which will arise in practice with reasonably good zinc sulphate, be ample. Another rule would be to add the zinc oxide gradually until the solution became slightly milky. The solution when put into the cell should not contain any free zinc oxide; if it does then, when mixed with the mercurous sulphate, zinc sulphate and mercurous oxide are formed; the latter may be deposited on the zinc, and affect the electro-motive force of the cell. The difficulty is avoided by adding as described about 12 per cent. of mercurous sulphate before filtration: this is more than sufficient to combine with the whole of the zinc oxide originally put in, if it all remains free; the mercurous oxide formed together with any undissolved mercurous sulphate is removed by the filtration.

The Mercurous Sulphate.—The treatment of the mercurous sulphate has for its object the removal of any mercuric sulphate which is often present as an impurity.

Mercuric sulphate decomposes in the presence of water into an acid and a basic sulphate. The latter is a yellow substance—turpeth mineral—

practically insoluble in water: its presence at any rate in moderate quantities has no effect on the cell. If, however, it is formed the acid sulphate is formed also. This is soluble in water and the acid produced affects the electro-motive force. The object of the washings is to dissolve and remove this acid sulphate, and for this purpose the three washings described in the specification will in nearly all cases suffice. If, however, a great deal of the turpeth mineral is formed it shows that there is a great deal of the acid sulphate present, and it will then be wiser to obtain a fresh sample of mercurous sulphate rather than to try by repeated washings to get rid of all the acid.

The free mercury helps in the process of removing the acid, for the acid mercuric sulphate attacks it, forming mercurous sulphate and acid which is washed away.

The cell may be sealed in a more permanent manner by coating the marine glue, when it is set, with a solution of sodium silicate and leaving it to harden.

Appendix.

August 12, 1892.

Dear Sir,—I am desired by the Electrical Standards Committee of the British Association to communicate to the Electrical Standards Committee of the Board of Trade the enclosed extract from their report made to the Association on August 9, 1892.

I remain, yours faithfully,
(Signed) R. T. Glazebrook,
Secretary, Electrical Standards Committee
of the British Association.

To Sir Thomas Blomefield,
Secretary, Electrical Standards Committee
of the Board of Trade.

Extract from the Report of the Electrical Standards Committee of the Association, *August* 9, 1892.

The following resolutions were agreed to:—

1. That the resistance of a specified column of mercury be adopted as the practical unit of resistance.

2. That 14·4521 grammes of mercury in the form of a column of uniform cross-section 106·3 centimetres in length at 0° C. be the specified column.

3. That standards in mercury or solid metal having the same resistance as this column be made and deposited as standards of resistance for industrial purposes.

4. That such standards be periodically compared with each other, and also that their values be redetermined at intervals in terms of a freshly set-up column of mercury.

It was further agreed that these resolutions be communicated to the Electrical Standards Committee of the Board of Trade.

With regard to the units of current and electro-motive force it was agreed that the number ·001118 should be adopted as the number of grammes of silver deposited per second from a neutral solution of nitrate of silver by a current of 1 ampere, and the value 1·434 as the electro-motive force in volts of a Clark cell at 15° C.

Dr. von Helmholtz expressed his full concurrence in these decisions, which are, as he informed the Committee, in accord with the recommendations which have already been laid by the Curatorium of the Reichsanstalt, as well as by himself before the German Government.

APPENDIX II.

Experiments on the Effects of the Heating produced in the Coils by the Currents used in Testing. By R. T. GLAZEBROOK.

Various circumstances (notably the experiments of Mr. Griffiths [1]) had made it appear probable that the heating effect in the coils produced by the current used in making the resistance test might be sufficient to affect the results of the tests. Some experiments were made to examine the point directly.

The resistance of a coil of 100 ohms (nominal value) was measured in the usual way, *i.e.* by making a Wheatstone's bridge of four coils whose nominal values were ·1, 10, 10, and 100 ohms. If the coils had been accurate there would have been a balance; as it was, one of the 10-ohm coils needed to be shunted, and the adjustment was made by determining the value of the shunt when no current passed through the galvanometer.

As the current in the battery circuit was increased by varying the number of cells this shunt decreased in value, showing that the effect of the heating was to produce an apparent diminution of the resistance of the 1000-ohm coil. This, of course, is as would be anticipated; for $\frac{10}{11}$ of the current goes through the 1-ohm and one of the 10-ohm coils; the remaining $\frac{1}{11}$ goes through the 10-ohm and the 100-ohm. The rise of temperature will clearly be greatest in the first 10-ohm coil, and to counterbalance the increase in resistance produced thereby it becomes necessary to reduce the shunt.

The following readings were obtained:—

Current in Amperes	Shunt in 1000 Ohms	Correcting Factor
·05	35·5	1 − ·00028
·09	32·5	·00031
·12	[2] 30	·00033
·14	30·5	·00033
·15	29·5	·00034

The true value of the 100-ohm is given by taking the product of the values of the two 10-ohm coils at the temperature of the observations, dividing by the value of the 1-ohm and multiplying by a factor representing the effect of the shunt.

During the above observations the temperatures remained steady, the factor changed from 1—·00028 to 1 — ·00034. Thus the resistance of the 100-ohm coil changed by ·034 — ·028, or ·006 ohm.

The apparatus was not sensitive with a smaller current; the effect,

[1] *Phil. Trans.*, 1893.

[2] Only one observation at this current was made; the others are the mean of several.

however, will vary as the square of the current; and, since trebling the current produces so small a change, we may infer that the total effect is itself small.

Another coil gave the following results:—

Current in Amperes	Shunt in 1000 Ohms	Correcting Factor
·05	48	1 − ·000208
·09	45	·000222
·12	43	·000233
·14	41	·000244
·15	40	·000250

indicating a change in the measured resistance of ·0042 ohm on 100 ohms.

It is clear, therefore, that the effect of heating is small, though appreciable when currents approaching ·15 ampere are used.

APPENDIX III.

On Standards of Low Electrical Resistance. By J. VIRIAMU JONES, *Principal and Professor of Physics in the University College, Cardiff.*

The preparation of standards of low electrical resistance of from ·001 to ·0001 ohm seems to be a matter of some importance at the present time. These standards are already in request among engineers, and it becomes of interest to consider how they may best be measured to a percentage accuracy comparable with that with which the standard ohm is known.

Such standards of low resistance may be derived by potentiometer methods from the standard ohm by a series of downward steps. But this is from one point of view roundabout. The method of measuring the ohm that seems in all its details most accurate is that of Lorenz. In this method the ohm itself is derived from the measurement of a small resistance. It is simply going up and down again to prepare from the ohm so derived the required small resistance standards, and it is more direct and more accurate to measure the latter directly in absolute measure.

'In Lorenz's method a metallic disc is made to rotate in the mean plane of a coaxial standard coil. Wires touching the centre and circumference of the disc are led to the ends of the resistance to be measured, and the same current is passed through this resistance and the standard coil. The connections being rightly made, we may by varying either the rate of rotation of the disc or the resistance measured so arrange matters as to have no change of current in the circuit of the disc and wires joining it to the ends of the resistance, when the direction of the current through the resistance and the standard coil is changed. When this arrangement is effected there is a balance between the electromotive force, due to the motion of the disc in the magnetic field of the current in the standard coil, and the difference of potential at the ends of the resistance, due to

the current traversing it. If this adjustment be made we will say that the apparatus is in an equilibrium position.'[1]

If M=coefficient of mutual induction of standard coil and circumference of disc,
n=rate of rotation of disc (number of revolutions per second),
R=resistance,
γ=current through standard coil and resistance,

then in an equilibrium position

$$Mn\gamma = R\gamma,$$

or

$$R = Mn.$$

I do not think that electricians have as yet realised the accuracy and ease with which absolute measurements of resistance may be made by this method. The absolute measurement involves measuring first the coefficient of mutual induction of the standard coil and the circumference of the rotating disc, and secondly the rate of rotation of the disc.

Now it lies well within the resources of modern mechanical engineering to make a standard coil and disc of dimensions known to an accuracy considerably greater than 1 in 10,000, the coil being constructed of a single layer of wire wound in a screw thread cut on a cylinder of large diameter; and the measurement of the rate of rotation to equal accuracy is a simple matter. There is difficulty in maintaining a rate of rotation constant to this figure for four or five minutes, but with the closest attention to the lubrication of all the bearings this also might be accomplished. Such constancy is well worth striving for, as the ease with which measurements of resistance can be made by the method largely depends upon it.

I do not propose on this occasion to enter into the details of the method I have adopted in making the measurements, the results of which I have now to bring before the Section. But it will perhaps be of interest if I say a few words about the time-measurement.

In measuring a resistance we have to find the rate of rotation corresponding to an equilibrium position. It is easiest in practice to determine this by interpolation from two determined rates of rotation (near together, and respectively slower and faster than the required rate) and the galvanometer deflections corresponding to them, so that each determination of resistance involves two determinations of galvanometer deflection and the rates of rotation corresponding to them.

In order that the galvanometer deflection may be obtained with sufficient accuracy from a limited number of reversals (in my observations the number has been almost uniformly thirty-three, taking about four minutes in each case) the brush at the circumference of the disc needs to be perforated and to be supplied with a constant stream of mercury. Such a brush in its best condition almost entirely eliminates the continual jerking of the galvanometer needle consequent on thermo-electric changes at the point of contact of brush and disc. A multiplication of such brushes at three or four points of the circumference would do this even more completely.

During the four or five minutes' run the rate of rotation is referred by

[1] Vide *Phil. Trans.*, 1891, A, p. 2, 'On the Determination of the Specific Resistance of Mercury in Absolute Measure.'

a stroboscopic method to a suitable tuning-fork provided with riders and maintained in vibration electrically. The observer at the fork can shunt more or less current through the electromotor driving the disc, and in this way maintains the rate of rotation as constant as he can. But though the electrically maintained fork is useful for purposes of control it cannot be relied on to give us the rate of rotation. Its vibration period is not within my experience constant to the degree of accuracy required. If stopped and set going again it may start with a period different by several parts in 10,000. No previous determination of the period of the fork can therefore be relied on to give us the rate of rotation, though once started the fork goes sufficiently uniformly to give us a means of control.

Accordingly it is necessary to measure the rate of rotation during each run while the galvanometer observations are being made. The rotating disc is, by means of an eccentric attached to its axle, made to record its revolutions on the tape of a Bain's electro-chemical telegraph instrument side by side with the record of the standard clock. We have, then, a time record exactly corresponding to the period of observation of the galvanometer deflections. During the run the observer at the galvanometer calls out the galvanometer readings, while the observer at the tuning-fork controls the speed, and the Bain's instrument records it.

I have made in this way a number of measurements during the months of July and August of a standard resistance of approximately ·0005 ohm, prepared last year by my assistant, Mr. Harrison, and a student in my laboratory, Mr. Parker, with the following results:—

July 17, morning	·00050016
„ 17, afternoon	·00050016
„ 19, morning	·00050015
Aug. 2, afternoon	·00050020
„ 3, morning	·00050021
„ 4, „	·00050016
„ 4, afternoon	·00050013
„ 5, morning	·00050019
„ 9, „	·00050021
„ 9, afternoon	·00050018
Mean	·00050017

The maximum divergence from the mean is ·00000004, or about one part in 12,000. Mr. Crompton has recently been issuing standards of low resistance made of manganine sheets, and he was kind enough, at my suggestion, to send me one for measurement towards the end of July. It was prepared in his laboratory as a derivative from the Cambridge ohm by means of his potentiometer. Its value so given was ·00050175 at 23° C. Its temperature coefficient appears, from the measurements made in Mr. Crompton's laboratory, to be so small that we need hardly consider it for our present purpose. My measurements of this standard were as follows:—

July 29, morning	·00050219
Aug. 1, „	·00050225
„ 1, afternoon	·00050219
„ 2, morning	·00050226
Mean	·00050222

which differs from Mr. Crompton's value by something less than one part

in 1000. Mr. Crompton's resistance is a rectangular sheet of manganine, and the potential terminals are two screws inserted at a suitable distance apart in the median line. The screws are not soldered. I thought it would be of interest to unscrew them, screw them up again, and remeasure the resistance. The results were—

August 10, morning	·00050328
" 10, afternoon	·00050322
" 10, "	·00050327
Mean . .	·00050326

indicating a variation of about one part in 500. I unscrewed them again, and after screwing them made a new measurement with the following results:—

August 11, morning	·00050398
" 12, "	·00050403
Mean . .	·00050401

which, compared with the first value ·00050222, shows a variation of, approximately, one part in 280.

We may therefore conclude that if an accuracy of $\frac{1}{10}$th per cent. is required of a standard so constructed its potential terminals ought not to be meddled with after its resistance has been determined.

In making these measurements my direct object has been to obtain an accurate and ready method of measuring standards of low resistance. But I think something more than this comes out of them. It would be possible in the light of our present experience to construct a Lorenz apparatus considerably more accurate and easier to use than that in my laboratory at Cardiff. Such an apparatus placed, let us suppose, in the National Laboratory, of which we have heard a good deal at recent meetings of the British Association, might with advantage be kept in constant use, not only for the calibration of low resistances, but also as embodying in concrete form a proper ultimate standard of electrical resistance. We have not in our electrical standard legislation given full credit to the mechanical engineer for what he can do for us; and I think that a coefficient of mutual induction arranged, as in the Lorenz method, so as to be easily combined with a time would afford a more satisfactory standard of resistance than any wire coil or coils, and one easier to use for purposes of ultimate reference than any mercury column.

The Application of Photography to the Elucidation of Meteorological Phenomena.—Third Report of the Committee, consisting of Mr. G. J. Symons (*Chairman*), Professor R. Meldola, Mr. J. Hopkinson, *and* Mr. A. W. Clayden (*Secretary*). (*Drawn up by the Secretary.*)

Your Committee beg to report that their work has progressed slowly during the last year, though it has been greatly hindered by the appointment of their secretary as principal of the new Technical and University Extension College at Exeter. The large amount of work involved in the

organisation of so novel a type of institution has left little opportunity for carrying on the work of the Committee.

Having been thus obliged to postpone much of the work they hoped to carry out, they have not drawn last year's grant.

Nevertheless, considerable progress has been made. The number of persons who have sent in their names as willing to contribute has been added to, the photographs in your Committee's collection have increased from 361 to 467, and the objects of the Committee have again been brought before some of the most important photographic societies.

The result is that the secretary is continually receiving letters asking for directions for the photography of clouds, for the loan of lantern slides, and general instruction, the furnishing of which your Committee consider by no means the least useful part of their functions.

A fairly exhaustive trial has been made of the comparative merits of the Sandell plates, and slow plates of the photomechanical type; from which it appears that the double film does not possess for cloud photography any advantage over the older type of plate. Since also the management of the latter after exposure is the easier, your Committee adhere to the decision given last year, that the black glass mirror and slow plate really provide the easiest means of securing good cloud pictures.

Attention must be drawn to the excellent pictures of clouds on the High Alps which have been received from Mr. Greenwood Pim, who has expressed his willingness to turn his attention to the photography of high clouds.

With regard to cloud photographs generally, your Committee feel that their collection already includes sufficiently good examples of all the commoner varieties of cloud which are capable of being so represented, and therefore think that there is no scientific object to be served in simply multiplying prints. Consequently, during the past year they have not sought such contributions, but in soliciting aid have invited observers to study especially the changes of high-level clouds. This is a work of considerable difficulty, and there are probably few persons who possess at once the requisite skill and sufficient leisure.

The records of cloud forms may thus be said to have been secured, and the next question is, How may they be utilised 'for the elucidation of meteorological phenomena'?

Upon what problems do they bear? This is easily answered. They should give first the means of settling precisely what connection there is between particular cloud forms and other atmospheric conditions, and in the next place they should give a clue to the explanation of their own forms.

In order to attack the first problem the great want is an efficient cloud atlas of the higher clouds, such as was undertaken some time ago by the International Committee. This atlas has not yet been published, and in it, moreover, it is proposed to arrange clouds under the names suggested by Messrs. Hildebrandsson and Abercromby, a system which English meteorologists have not yet adopted. Indeed, as your Committee have observed in a previous Report, the system of nomenclature should follow and not precede the study of the two problems stated.

The varieties of the lower clouds are pretty well understood; it is with the higher clouds that all difficulties arise. Your Committee therefore suggest that they should be empowered to arrange for the publica-

tion of a provisional cloud atlas, or one section of it, under the following conditions. Divide all clouds into the three great groups, Cumulus, Stratus, and Cirrus. Publish volumes dealing with each of these great groups, *not naming* the subordinate varieties, but assigning merely numbers. Thus, supposing there are ten varieties of Cirrus—call them No. 1, No. 2, &c.; then, if there are ten varieties of cirro-cumulus, let these be numbered from eleven upwards.

It seems that if such an atlas were distributed to a number of observers who are in the habit of making eye-estimations of the quantity of cloud, it would be quite easy for them to record also the numbers of the respective types of cloud visible. Since these observations would be made by meteorologists, and at the same time as records of temperature, pressure, &c., the results could not fail to be of real importance.

Again, a meteorologist armed with such an atlas would be able to note changes of form from one type to another almost as well as the actual photographer.

Lightning Photographs.

Not many new photographs of lightning have been received, but they all agree with the others in the Committee's collection in showing what has been called the narrow ribbon structure. There has not yet been any opportunity of ascertaining whether this structure is shown in negatives on paper, but it is visible in negatives taken on thin films. This fact confirms the opinion already expressed by your Committee, that it represents the true form of a lightning flash. Moreover, it cannot be caused by reflection from the back of the plate, because if so it would be most evident in the brighter parts of the flash, whereas it is most evident in the fainter; also, it would be more pronounced in the margins of the plate than in the centre, and the apparent orientation of the ribbon would vary according to the position on the plate. None of these things are noticeable. The major thickness of the ribbon seems to set itself in a particular direction, which is constant for all parts of a branched or other flash, whatever may be the position of the image on the plate. It is also not a whit more obvious in the margins of the plate than in the centre. Lastly, it is almost invariably shown more or less plainly; why, then, should it be supposed to be due to some error of observation?

It has lately been suggested that it is produced by marginal deformation of the image. Let us put aside for a moment the fact that the phenomenon is not marginal at all. Now, if a lens be used which will not cover the plate properly, so that the margins are out of focus, or if the camera be purposely put out of focus, it is quite true that the image of an electric spark may be expanded into a broad ribbon. But this is characterised by both the margins of the ribbon being brighter than the centre, while in the true narrow ribbon structure, as shown by lightning, the whole is equally bright, or *one* margin is bright and the other the faintest part of the image. The explanation is clearly incorrect.

It may be useful here to draw a definite distinction between a lightning 'flash' and a lightning 'discharge.' Flashes last only a short time, a mere fraction of a second, though probably a considerably larger fraction than was at one time supposed. The eye is not conscious of any variations of brilliancy during the flash, and a camera moving with considerable velocity does not resolve it into a number of components.

Discharges may consist of a single flash, but they frequently consist of a series of flashes following one another with considerable rapidity along the same or related paths. The eye is often able to detect alternations of brilliancy during a discharge, and may resolve it, as a moving camera will, into a series of flashes accompanied by a persistent luminosity, which it has already been suggested is probably the flame of burning nitrogen.

Last year your Committee referred to a photograph taken by Mr. Glew at Brixton. This was taken in a camera the lens of which was attached to the hammer of an electric bell and kept in oscillation during exposure. The object was to deduce from the known rate of movement of the lens the duration of the discharge. Unfortunately, however, there is nothing to show in which direction the lens was travelling at the moment of each component flash.

There is one very simple method by which it is quite possible to make a rough measurement of the duration of a discharge. Let two observers, A and B, agree that A shall carefully notice the seconds hand of his watch while B looks at the sky to be sure that A does not confuse two separate discharges. If the night is otherwise dark, A will see the hand only when the face is illuminated by the lightning. The secretary to your Committee has, with the aid of Mrs. Clayden, made many such observations, and has found that a lightning discharge often lasts as much as two or three seconds, and may extend further, the longest time hitherto observed being no less than seven seconds. During these times, though the brightness of the light varied considerably, it was quite possible to watch the hand moving steadily, and not in a series of jerks, as must have been the case if the continuity of illumination had been an illusion due to persistence of vision. In a similar way it is quite possible to follow the movements of swaying tree-tops and other objects. It was noted with some surprise that the light, as far as the eye can see, is often perfectly steady for as much as a couple of seconds. Since beginning these observations not a single discharge has been noted of sufficient brevity to prevent any movement of the watch hand from being seen.

Now, although such observations are rough, their bearing upon lightning photography is important.

An argument commonly advanced to prove that all photographs of reduplicated flashes are due to movement of the camera is that the track to be followed by successive flashes in a given discharge is marked out by the first, which creates a path of minimum resistance in the form of a partial vacuum.

But it seems to be forgotten how far this tube of rarefied air must be moved, and how far the discharging point of the cloud (so to say) may be displaced by the movement of the air. We know that the wind is often quite strong during a thunderstorm.

Now, a movement of one mile an hour corresponds to 17·6 inches a second.

Suppose, therefore, we take the first seven values of the Beaufort scale and see how far such a tube of minimum resistance would be displaced during the existence of a discharge.

Hence it appears that if a discharge lasts as long as three seconds, the path of minimum resistance marked out by the first flash might be displaced as much as fifty yards by a strong breeze. Moreover, since the clouds would be moving at the same rate as the upper part of the vacuous

Force Beaufort scale	Miles per hour	Inches per second	Displacement in feet (discarding fractions)			Displacement in metres
			1 sec.	2 secs.	3 secs.	1 sec.
0	3 or less	53	4	9	13	1·3
1	8	141	12	23	35	3·6
2	13	229	19	38	57	5·8
3	18	317	26	53	79	8·1
4	23	405	34	67	101	10·3
5	28	493	41	82	123	12·5
6	34	598	50	100	150	15·2

track, there would be no disturbance of its relation to the discharging point.

It is frequently observed in photographs of reduplicated flashes that the various components do not follow absolutely similar paths, and it is often seen that the departure from similarity is near the ground.

Surely this is exactly what would be expected if the path of least resistance were swept along as suggested. The movements of the wind are not uniform, and the tube would frequently get bent or broken, such an event being most probable to occur within reach of eddies from the ground. It may be pointed out that the reduplicated flash photographed by the secretary to your Committee in a stationary camera was taken at right angles to that in which the storm and wind were travelling.

Movement of the camera or lens or plate would necessarily exaggerate the reduplication where it might not otherwise have been detected, but there can be no doubt that a single discharge often lasts for several seconds, and therefore that any path of minimum resistance created by the first component flash must be moved to an extent quite sufficient to reveal the multiple structure to the eye and to the camera.

It seems, moreover, that the narrow ribbon structure may be attributed to much the same cause.

In conclusion, your Committee have to state that their scheme of an atlas of typical clouds cannot be carried out without considerable expenditure, and they suggest that they be reappointed with a grant of 50*l.* As they did not draw the 15*l.* voted last year, this is really an application for only 35*l.* for that which they believe would be a valuable piece of work.

The Best Methods of Recording the Direct Intensity of Solar Radiation.—Ninth Report of the Committee, consisting of Sir G. G. STOKES (*Chairman*), Professor A. SCHUSTER, Mr. G. JOHNSTONE STONEY, Sir H. E. ROSCOE, Captain W. DE W. ABNEY, Professor H. MCLEOD, *and* Mr. G. J. SYMONS. (*Drawn up by* Professor MCLEOD.)

DURING the last year Mr. Casella has constructed for the Committee a thermometer with a lenticular bulb similar to that described in previous Reports, but consisting of colourless instead of green glass. As stated in the last Report, there are great difficulties in constructing an instrument with a green-glass bulb, and it was believed that there would be little

difference in the readings obtained with a thermometer of ordinary white glass.

On May 22 three sets of observations were made, two with the green-glass and one with the white-glass thermometer: those with the green were made between X.17 and X.50 and between XI.35 and XI.53, that with the white-glass instrument between XI.0 and XI.25.

The observed excesses of temperature of the green-glass thermometer above the temperature of the case were 48°·3 F. and 49°·3. The observed excess of the white glass was only 32°·8. The corresponding calculated excesses obtained by the method described in the last Report were respectively 50°·29, 49°·24, and 33°·30.

It is thus seen that the white-glass bulb rises to about two-thirds of the excess indicated by the green-glass bulb. This, however, is no disadvantage, for when the temperature of the insolation thermometer is much above that of the case the simple law which for smaller excesses connects the rate of cooling with the difference of temperatures is no longer a sufficiently near approximation, and the reduction of the observed results becomes more difficult.

As the simultaneous reading of the three thermometers is not an easy operation, an attempt has been made to replace them by two thermo-electric junctions. A copper disc, 20 mm. in diameter and about ·75 mm. thick, was soldered at its centre to a piece of iron wire. The wire was so bent that when the centre of the disc opposite to the soldered joint is exactly behind the hole in the copper cube, the other end of the wire makes contact with the copper cube midway between the front and back. To the edge of the disc a thin copper wire is soldered, which passes through a glass tube in the central opening of the cube, and is thus insulated from it. The experiment being only preliminary, the iron wire has been fixed in a hole drilled in the copper plug which usually holds the insolation thermometer, the glass tube carrying the insulated wire being passed through the hole in the same plug. The other terminal from the copper cube is made by fixing a piece of copper wire in the plug which closes the hole of the case thermometer B in front of the cube. In a permanent instrument a binding screw should be attached to the cube in the plane of the disc. To increase the absorption of heat by the copper disc, it was blackened by being placed for a short time in sulphuretted hydrogen. The black surface thus obtained does not, however, completely absorb the radiation, for, on throwing a beam of sunlight on it, it is observed that some of the light is scattered. The surface thus obtained may, in addition, be not permanent.

The terminals of the thermo-couples were connected to a reflecting galvanometer of ·97 ohm resistance, and the disc exposed to the rays of the sun, the lens of the instrument being used. The deflection of the galvanometer became steady after an exposure of from five to eight minutes, whereas twenty minutes were required when the green-glass-bulb thermometer was used.

In order to determine the value of the deflections a double thermo-couple was made by soldering to two stout copper wires a bent piece of thick iron wire. Close to the junctions delicate thermometers were tied, and the apparatus was so arranged that the thermo-junctions and thermometer bulbs could be plunged in test tubes containing paraffin oil: one of these test tubes could be heated, and the connections were so made that the current produced by the heated junction opposed that from the

actinometer. Whilst the disc in the actinometer was exposed to the solar radiations, one of the thermo-junctions was heated, and when the galvanometer indicated that no current was flowing the thermometers were read. In one case, in which a deflection of 172 divisions was obtained, the current was balanced by a difference of temperature of the two junctions of 8°·27 C.

If an instrument of this kind could be made photographically self-recording it would constitute an excellent sunshine-recorder, giving not only the time of the shining of the sun, but also a measure of its intensity. An ordinary reflecting galvanometer would not be very suitable for this purpose, for variations of the earth's magnetism and the possible movement of magnetic bodies in its neighbourhood would vitiate the results. An instrument on the principle of the D'Arsonval galvanometer would be more appropriate, but a few experiments made with such an instrument have not given satisfactory results. Another source of error must be mentioned, namely, the variation of the resistance of the long conducting wires by changes of temperature. No doubt all these difficulties might be overcome in a properly appointed observatory.

On the Present State of our Knowledge of Electrolysis and Electro-chemistry. Report by W. N. SHAW *and* T. C. FITZPATRICK.

Table of Electro-chemical Properties of Aqueous Solutions, compiled by T. C. FITZPATRICK.

The comparison of the numerical results of electrolytic observations is rendered difficult from the fact that the data are scattered in various periodicals and expressed by different observers in units that are not comparable without considerable labour. The following table has been compiled with the object of facilitating the comparison.

In the table are included all the observations, as far as they are known to the compiler, for the metallic salts and mineral acids; but amongst the solutions of organic substances are not given all those for which Ostwald has made observations, as it was thought that they would add unnecessarily to the size of the table. Observations for a number of additional substances will be found in Ostwald's papers in 'Journal für Chemie,' vols. xxxi., xxxii., and xxxiii., and in the 'Zeitschrift für physikalische Chemie,' vol. i. With this restriction it is hoped that no important observations have been omitted, and that in the reduction of results, expressed in such varied units, the table is sufficiently free from mistakes for it to be of service. The data included refer to the strength and specific gravity of solutions, with the corresponding conductivities, migration constants, and fluidities. The several columns are as follows:—

I. Percentage composition, *i.e.* the number of parts by weight of the salt (as represented by the chemical formula) in 100 parts of the solution.

II. The number of gramme molecules per litre, *i.e.* the number of grammes of the salt per litre divided by the chemical equivalent in grammes, as given for each salt.

III. The specific gravities of the solutions: in most cases the specific gravities of the solutions are not given by the observers, and the numbers

given have been deduced from Gerlach's tables in the 'Zeitschrift für analytische Chemie,' vol. viii. p. 243, &c.

IV. The temperatures at which the solutions have the specific gravities given in the previous column for the given strength of solution.

V. The conductivity, as expressed by the observer. In the cases in which the observer has expressed his results for specific molecular conductivity no numbers are given in this column.

VI. The temperature at which the conductivities of the solutions have been determined.

VII. The temperature coefficient referred to the conductivity at 18°, *i.e.* $\frac{1}{k_{18}}\left(\frac{\delta k_{18}}{\delta t}\right)$.

VIII. The specific molecular conductivity of the solutions at 18° in terms of the conductivity of mercury at 0°; specific molecular conductivity is the ratio of the conductivity of a column of the liquid 1 centimetre long and 1 square centimetre in section to the number of gramme equivalents per litre.

In some few cases in which no temperature coefficients have been determined the results have been given for the temperature at which the observations were made.

The numbers given in the column are the values for the specific molecular conductivity $\times 10^9$.

IX. This column contains the values for specific molecular conductivity at 18° in C.G.S. units: they are obtained from those in the previous column by being multiplied by the value of the conductivity of mercury at 0° in C.G.S. units. This factor is $1{\cdot}063 \times 10^{-5}$.

X. The migration constant for the anion; for instance, in the case of copper sulphate ($CuSO_4$) for (SO_4).

XI. The temperatures at which the migration constants have been determined.

XII. The number of gramme molecules per litre, as defined for column II., for which the fluidity data are given in the following columns.

XIII. The fluidity of the solutions of the strength given in the previous column.

Most of the results given for the fluidity of solutions are expressed in terms of the fluidity of water at the same temperature: to obtain the absolute values for the solutions they have been multiplied by the value for the fluidity of water at the given temperature. The values used for this purpose have been taken from Sprung's observations for the viscosity of water given in 'Poggendorff's Annalen,' vol. clix. p. 1.

To obtain the values for fluidity in C.G.S. units the numbers in this column must be multiplied by the factor ·1019.

XIV. The temperature at which the solutions have the fluidity given in the previous column.

XV. The temperature coefficient of fluidity at 18°, that is, $\frac{1}{f_{18}}\left(\frac{\delta f_{18}}{\delta t}\right)$.

XVI. In the last column are given the references to the various papers from which the data are taken: against each reference will be found a number, which appears also against the first of the data which have been taken from the paper in question.

TABLE OF ELECTRO-CHEMICAL PROPERTIES OF SOLUTIONS IN W[illegible]

HYDROCHLORIC ACID

Equivalent Gramme Molecule, HCl, 36.46

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Temperature	Temperature Coefficient	Specific Molecular Conductivity [illegible]	Specific Molecular Conductivity [illegible]	a	Temperature	Equivalent Gramme Molecules per Litre	[illegible]	Temperature	Temperature Coefficient
·0000364	·00001	—	°	—	18°	—	1264[1]	1333	—	°	—	—	°	—
·000073	[illegible]	—	—	—	18	—	2057	2186	—	—	—	—	—	—
·000219	·00006	—	—	—	18	—	2968	3166	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3171	3471	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3340	3550	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3440	3636	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3455	3672	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3465	3672	—	—	—	—	—	—
[illegible]	[illegible]	—	—	—	18	—	3438	3654	—	—	—	—	—	—
[illegible]	·01	—	—	—	18	·0159	3416	3641	—	—	—	—	—	—
·047	·0128	1·0062	5·5			—	—	—	210[2]	—	—	—	—	—
·109	[illegible]	—	—	—	18	—	3369	3581	—	—	1·51	·923[4]	20	·0233
·182	·05		—	—	18	—	3330	3540			2·87	·850	20	·0214
[illegible]	·085	1·00[illegible]6	7·8			—	—	—	216	—	6·03	·736	20	·0190
[illegible]	·1	1·0012	15·5		18	—	3244	3419	—	—	9·47	·570	20	·0185
·704		—	—	—		—	—	—	·171		—	—	—	
1·2	·3	1·0062	7·6	—	—	—	—	—	·161	—	—	—	—	
1·807	·5	1·0088	16·5		18	—	3047	3207	—	—	—	—	—	
2·6[illegible]	·711	1·01[illegible]	7·6	—	—	—		—	·168		—	—	—	—
3·58	1·0	1·0179	16·8	—	18	—	2780	2955	—	—	—	—	—	—
9·20	2·14	1·0472	7·4		—	—	—	—	·193	—	—	—	—	—
10·41	3·0	1·0501	15·5		18	—	2010	2136	—	—	—	—	—	—
16·8	5·0	1·08[illegible]2	15·5		18	—	1420	1509	—	—	—	—	—	—
25·50		—	—	—	—	—	—		·319	—	—	—	—	—
31·5	10·0	1·1532	15·5	—	18	—	600	638	—	—	—	—	—	—
·000225	[illegible]		—	83·2[3]	25	—	—	3381	—	—	—	—	—	—
·00045	[illegible]		—	86·6	25	—		3619	—	—	—	—		—
·00090	·000244	—	—	88·6	25	—	—	3601		—	—	—		—
·00178	[illegible]	—	—	[illegible]	25	—	—	3637		—	—			
·00355	[illegible]	—	—	[illegible]	—		—	3[illegible]						
·0071	[illegible]	—	—	89·6	25	—		3611	—	—	—	—		—
·0142	[illegible]	—	—	89·2	25	—	—	3625	—	—	—	—	—	—
·0285	·0078	—	—	88·7	25	—		3605	—	—	—	—		—
·057	[illegible]		—	88·1	25	—	—	[illegible]						
·114	[illegible]			[illegible]	25		—	[illegible]						

Notes

[1] Kohlrausch, *Wied Annal* vol xxvi p 1[illegible]6

[2] Ostwald, *Journal fur Chemie*, vol xxxi p 437

[3] Hittorf, *Pogg Annal* vol cvi p 395

[4] Grotian, *Pogg Annal* [illegible]

1·807	·5	1·0086	15·5	77·9	25	—	—	3166	—	—	—	—	—	—
·0286	·00784	—	—	2·66 [5]	18	—	3395	3609	—	—	—	—	—	—
·057	·0157	—	—	5·28	18	—	3369	3581	—	—	—	—	—	—
·114	·0314	—	—	10·4	18	—	3323	3532	—	—	—	—	—	—
·228	·0627	—	—	20·6	18	—	3289	3496	—	—	—	—	—	—
·456	·1255	1·0018	15·5	40·5	18	—	3234	3438	—	—	—	—	—	—
·910	·251	1·0046	15·5	78·7	18	—	3138	3336	—	—	—	—	—	—
1·813	·502	1·0090	15·5	151·3	18	—	3014	3204	—	—	—	—	—	—

l'Acad. de St. Pétersbourg, vol. xxvi.

POTASSIUM CHLORIDE.

Equivalent Gramme Molecule, KCl, 74·59.

·0000746	·00001	—	—	—	18	—	1216 [1]	1293	—	—	—	—	—	—
·000149	·00002	—	—	—	18	—	1217	1294	—	—	—	—	—	—
·000448	·00006	—	—	—	18	—	1212	1288	—	—	—	—	—	—
·000746	·0001	—	—	—	18	—	1209	1285	—	—	—	—	—	—
·00149	·0002	—	—	—	18	—	1209	1285	—	—	—	—	—	—
·00448	·0006	—	—	—	18	—	1199	1275	—	—	—	—	—	—
·00746	·001	—	—	—	18	—	1193	1268	—	—	—	—	—	—
·0149	·002	—	—	—	18	—	1185	1260	—	—	·125	992 [3]	20	—
·0448	·006	—	—	—	18	—	1162	1235	—	—	·25	995	20	—
·0746	·01	—	—	—	18	0221	1147	1219	—	—	·5	997	20	—
·224	·03	—	—	—	18	—	1107	1178	·503 [2]	—	1·0	997	20	—
·372	·05	1·0019	15	—	18	—	1083	1151	—	—	1·466	987 [4]	20	·0219
·743	·1	1·0046	15	—	18	—	1047	1113	—	—	3·432	956	20	·0191
3·64	·5	1·0228	15	—	18	·0206	958	1018	—	—	—	—	—	—
5·15	·714	1·0342	7·2	—	—	—	—	—	·515	—	·0625	986 [5]	20	—
7·13	1·0	1·0457	18	—	18	·0199	919	977	—	—	·125	986	20	—
13·1	1·94	1·1034	4·5	—	—	—	—	—	·516	—	·25	987	20	—
17·1	2.55	1·1155	12·4	—	—	—	—	—	·516	—	·5	988	20	—
19·7	3·0	1·1359	15	—	18	·0170	827	879	—	—	1·0	990	20	—
·00746	·001	—	—	1·29 [6]	18	—	—	1250	—	—	1·0	997 [7]	20	—
·0746	·01	—	—	12·1	18	—	—	1206	—	—	—	—	—	—
·743	·1	1·0046	15	113·0	18	—	—	1130	—	—	—	—	—	—
1·48	·2	1·0096	15	220·0	18	—	—	1100	—	—	—	—	—	—
3·74	·5	1·0228	15	508·0	18	—	—	1016	—	—	—	—	—	—
7·13	1·0	1·0457	15	991·0	18	—	—	991	—	—	—	—	—	—
3·7	2·0	·0912	15	1888·0	18	—	—	944	—	—	—	—	—	—
9·7	3·0	1·1359	15	2742·0	18	—	—	914	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Hittorf, *Pogg. Annal.* vol. xcviii. p. 27.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.

[4] Sprung, *Pogg. Annal.* vol. clix. p. 1.

[5] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

[6] Bouty, *Journal de Physique*, vol. vi. p. 10.

[7] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

POTASSIUM CHLORIDE—*continued*.

Equivalent Gramme Molecule, KCl 74·59.

			°		°					°			°		
·00725	·000976	—	—	142·3[8]	25	·0221	—	1310	—	—	—	—	—	—	Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 85.
·0145	·00195	—	—	138·6	25	—	—	1276	—	—	—	—	—	—	
·029	·0039	—	—	134·8	25	—	—	1241	—	—	—	—	—	—	
·058	·0078	—	—	131·1	25	—	—	1207	—	—	—	—	—	—	Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.
·116	·0156	—	—	127·6	25	—	—	1174	—	—	—	—	—	—	
·232	·0312	1·0008	15	124·2	25	—	—	1143	—	—	—	—	—	—	
·0072	·00097	—	—	—	18	·0236	1180[9]	1254	—	—	—	—	—	—	
·0142	·0019	—	—	—	18	·0231	1140	1211	—	—	—	—	—	—	
·0283	·0038	—	—	—	18	·0222	1110	1180	—	—	—	—	—	—	
·0746	·0100	—	—	—	18	0220	1080	1148	—	—	—	—	—	—	
·137	·0184	—	—	—	18	·0218	1060	1127	—	—	—	—	—	—	

AMMONIUM CHLORIDE.

Equivalent Gramme Molecule, NH_4Cl, 53·5.

·0000535	·00001	—	—	—	18	—	1205[1]	1281	—	—	—	—	—	—
·000107	·00002	—	—	—	18	—	1209	1285	—	—	—	—	—	—
·000321	·00006	—	—	—	18	—	1215	1292	—	—	—	—	—	—
·000535	·0001	—	—	—	18	—	1209	1285	—	—	—	—	—	—
·00107	·0002	—	—	—	18	—	1204	1280	—	—	—	—	—	—
·00321	·0006	—	—	—	18	—	1197	1273	—	—	—	—	—	—
·00535	·001	—	—	—	18	—	1190	1265	—	—	·693	989[2]	20	—
·0107	·002	—	—	—	18	—	1180	1255	—	—	1·625	1009	20	—
·0321	·006	—	—	—	18	—	1157	1230	—	—	3·069	1005	20	—
·0535	·01	—	—	—	18	·0226	1142	1214	—	—	4·666	980	20	—
·1605	·03	—	—	—	18	—	1101	1171	—	—	—	—	—	—
·267	·05	1·0002	15·0	—	18	—	1078	1146	—	—	·95	996[3]	20	·0229
·534	·1	1·0013	15·0	—	18	—	1035	1100	—	—	1·925	985	20	·0212
·57	·107	1·0019	7·0	—	—	—	—	—	·508[5]	—	2·93	1011	20	·0198
2·65	·5	1·0084	15·0	—	18	·0204	948	1007	—	—	3·956	987	20	·019
3·44	·65	1·0113	9·8	—	—	—	—	—	·514	—	—	—	—	—
5·263	1·0	1·0165	15·0	—	18	·0198	907	964	—	—	1·0	998[4]	20	—
7·59	1·45	1·0241	9·8	—	—	—	—	—	·514	—	—	—	—	—
—	3·0	1·0461	15·0	—	18	·0172	825	877	—	—	—	—	—	—
15·92	3·12	1·0483	11·8	—	—	—	—	—	·517	—	—	—	—	—
—	5·0	1·0730	15·0	—	18	·0155	752	799	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 1.

[3] Grotian, *Pogg. Annal.* vol. clx. p. 262.

[4] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[5] Hittorf, *Pogg. Annal.* vol. xcviii. p. 33.

·334	·0625	1·0005	15·0	65·9 [6]	18	—	1054	1120	—	—	—	—	—	—
·667	·125	1·0018	15·0	127·5	18	—	1020	1084	—	—	—	—	—	—
1·331	·25	1·0042	15·0	244·0	18	—	976	1037	—	—	—	—	—	—
2·65	·5	1·0084	15·0	466·0	18	—	932	991	—	—	—	—	—	—
·0081	·00152	—	—	—	18	·0233	1200 [7]	1276	—	—	—	—	—	—
·0151	·00282	—	—	—	18	·0226	1150	1222	—	—	—	—	—	—
·0309	·00578	—	—	—	18	·0224	1120	1190	—	—	—	—	—	—
·053	·0099	—	—	—	18	·0224	1090	1159	—	—	—	—	—	—
·0942	·0176	—	—	—	18	·0221	1060	1127	—	—	—	—	—	—
·183	·0342	—	—	—	18	·0221	1030	1095	—	—	—	—	—	—

[6] Lenz, *Mémoire de l'Acad. de St. Pétersbourg;* vol. xxvi. No. 3.

[7] Vicentini, *Atti dell'Accad. di Torino,* vol. xx. p. 688.

SODIUM CHLORIDE.

Equivalent Gramme Molecule, NaCl, 58·5.

·000058	·00001	—	—	—	18	—	1024 [1]	1088	—	—	—	—	—	—
·000117	·00002	—	—	—	18	—	1028	1093	—	—	—	—	—	—
·000351	·00006	—	—	—	18	—	1027	1092	—	—	—	—	—	—
·000585	·0001	—	—	—	18	—	1029	1094	—	—	—	—	—	—
·00117	·0002	—	—	—	18	—	1018	1082	—	—	1·437	854 [2]	20	·0245
·00351	·0006	—	—	—	18	—	1014	1077	—	—	2·704	740	20	·0243
·00585	·001	—	—	—	18	—	1008	1071	—	—	5·013	558	20	·0252
·0117	·002	—	—	—	18	—	998	1061	—	—	—	—	—	—
·0351	·006	—	—	—	18	—	976	1037	—	—	—	—	—	—
·0585	·01	—	—	—	18	·0238	962	1023	—	—	1·0	896 [3]	20	—
·1755	·03	1·0006	15·0	—	18	—	920	978	—	—	—	—	—	—
·292	·05	1·0015	15·0	—	18	—	897	953	—	—	—	—	—	—
·31	·055	1·0023	5·6	—	—	—	—	—	·622 [5]	—	·0625	980 [4]	20	—
·583	·1	1·0038	15·0	—	18	—	865	919	—	—	·125	975	20	—
·945	·162	1·0068	17·4	—	—	—	—	—	·628	—	·25	963	20	—
2·865	·5	1·0207	15·0	—	18	·0220	757	804	—	—	·5	942	20	—
4·61	·814	1·0334	16·2	—	—	—	—	—	·634	—	1·0	890	20	—
5·62	1·0	1·0406	15·0	—	18	·0218	695	739	—	—	—	—	—	—
15·03	2·867	1·1159	8·6	—	—	—	—	—	·647	—	—	—	—	—
15·71	3·0	1·1171	15·0	—	18	·0213	528	561	—	—	—	—	—	—
22·34	4·477	1·1716	13·0	—	—	—	—	—	·648	—	—	—	—	—
24·6	5·0	1·1890	15·0	—	18	·0227	398	423	—	—	—	—	—	—
·365	·0625	1·0021	15·0	54·2 [6]	18	—	867	921	—	—	—	—	—	—
·728	·125	1·0050	15·0	104·2	18	—	834	886	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 13.

[3] Arrhenius, *Zeitschrift für Physik. Chemie,* vol. i. p. 295.

[4] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

[5] Hittorf, *Pogg. Annal.* vol. cvi. p. 374.

[6] Lenz, *Mémoire de l'Acad. de St. Pétersbourg,* vol. xxvi.

SODIUM CHLORIDE—*continued*.

Equivalent Gramme Molecule, NaCl, 58·5.

			°		°					°			°	
1·44	·25	1·0105	15·0	197·6	18	—	790	840	—	—	—	—	—	—
2·86	·5	1·0207	15·0	369·0	18	—	738	784	—	—	—	—	—	—
·0058	·000976	—	—	119·5 [7]	25	—	—	1089	—	—	—	—	—	—
·0115	·00195	—	—	116·3	25	—	—	1060	—	—	—	—	—	—
·023	·0039	—	—	112·1	25	—	—	1021	—	—	—	—	—	—
·046	·0078	—	—	110·1	25	—	—	1003	—	—	—	—	—	—
·092	·0156	—	—	107·0	25	—	—	975	—	—	—	—	—	—
·183	·0312	1·0006	15·0	104·0	25	—	—	948	—	—	—	—	—	—
·00643	·0011	—	—	—	18	·0236	970 [8]	1031	—	—	—	—	—	—
·00936	·0016	—	—	—	18	·0232	950	1010	—	—	—	—	—	—
·0287	·0049	—	—	—	18	·0232	920	978	—	—	—	—	—	—

[7] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 80.

[8] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

LITHIUM CHLORIDE.

Equivalent Gramme Molecule, LiCl, 42·5.

·0000425	·00001	—	—	—	18	—	965 [1]	1026	—	—	—	—	—	—
·000085	·00002	—	—	—	18	—	955	1015	—	—	—	—	—	—
·000255	·00006	—	—	—	18	—	945	1004	—	—	—	—	—	—
·000425	·0001	—	—	—	18	—	943	1002	—	—	—	—	—	—
·00085	·0002	—	—	—	18	—	938	997	—	—	—	—	—	—
·00255	·0006	—	—	—	18	—	926	984	—	—	1·908	741 [2]	20	·0252
·00425	·001	—	—	—	18	—	921	979	—	—	3·54	584	20	·0248
·0085	·002	—	—	—	18	—	911	968	—	—	7·365	313	20	·0247
·0255	·006	—	—	—	18	—	889	945	—	—	—	—	—	—
·0425	·01	—	—	—	18	·0232	875	930	—	—	—	—	—	—
·1275	·03	—	—	—	18	—	834	887	—	—	·125	957 [3]	20	—
—	·042	—	—	—	—	—	—	—	·674 [5]	—	·25	937	20	—
·212	·05	1·0006	15	—	18	—	811	862	—	—	·5	907	20	—
·424	·1	1·0021	15	—	18	—	775	824	—	—	1·0	863	20	—
—	·11	—	—	—	—	—	—	—	·699	—	—	—	—	—
—	·235	—	—	—	—	—	—	—	·718	—	—	—	—	—
2·985	·5	1·0126	15	—	18	·0229	661	703	—	—	1·0	857 [4]	20	—
—	·809	—	—	—	—	—	—	—	·739	—	—	—	—	—
4·146	1·0	1·0249	15	—	18	·0225	591	628	—	—	—	—	—	—
7·757	1·784	—	—	—	—	—	—	—	·738	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 17.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 38.

[4] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[5] Kuschel, *Wied. Annal.* vol. xiii. p. 295.

12·0	3·0	1·0700	15	—	18	·0218	421	447	—	—	—	—	—	—	[6] Fitzpatrick, *Phil. Mag.* (5th series), vol. xxiv. p. 377.
13·91	3·213	—	—	—	—	—	—	—	·753	—	—	—	—	—	
19·12	5·0	1·1110	15	—	18	·0220	303	322	—	—	—	—	—	—	
26·93	6·895	—	—	—	—	—	—	—	·773	—	—	—	—	—	
34·91	10·0	1·2173	15	—	18	·0251	106	113	—	—	—	—	—	—	
·0083	·00195	—	—	—	18	—	897 [6]	954	—	—	—	—	—	—	
·0165	·0039	—	—	—	18	·0234	882	938	—	—	—	—	—	—	
·0331	·0078	—	—	—	18	—	874	929	—	—	—	—	—	—	
·0662	·0156	—	—	—	18	—	849	902	—	—	—	—	—	—	
·1325	·0312	—	—	—	18	—	820	871	—	—	—	—	—	—	
·265	·0625	—	—	—	18	—	784	833	—	—	—	—	—	—	
·53	·125	1·0028	15	—	18	—	745	792	—	—	—	—	—	—	
1·056	·25	1·0063	15	—	18	—	694	738	—	—	—	—	—	—	

STRONTIUM CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $SrCl_2$, 79 02.

·00506	·00064	—	—	—	18	·0244	1070 [1]	1137	—	—	·969	867 [2]	20	·0244	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.
·0069	·00087	—	—	—	18	—	1040	1105	—	—	1·41	772	20	·0235	
·0111	·0014	—	—	—	18	·0240	1000	1063	—	—	3·31	611	20	—	
·0229	·0029	—	—	—	18	·0237	880	935	—	—	5·508	400	20	—	[2] Sprung, *Pogg. Annal.* vol. clix. p. 18.
—	·5	—	—	353 [5]	18	·0217	706	—	—	—	·125	954 [3]	20	—	[3] Mutzel, *Wied. Annal.* vol. xliii. p. 25.
—	1·0	—	—	640	18	·0212	640	—	—	—	·25	923	20	—	
—	1·5	—	—	882	18	·0208	588	—	—	—	·5	860	20	—	
—	2·0	—	—	1082	18	·0204	541	—	—	—	1·0	752	20	—	[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.
—	2·5	—	—	1250	18	—	500	—	—	—	—	—	—	—	
—	3·0	—	—	1387	18	—	462	—	—	—	·125	960 [4]	20	—	
—	3·5	—	—	1499	18	—	426	—	—	—	·25	941	20	—	[5] Kohlrausch, *Wied. Annal.* vol. vi. p. 148.
—	—	—	—	—	—	—	—	—	—	—	·5	911	20	—	
—	—	—	—	—	—	—	—	—	—	—	1·0	853	20	—	

BARIUM CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $BaCl_2$, 104.

·000104	·00001	—	—	—	18	—	1142 [1]	1214	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.
·000208	·00002	—	—	—	18	—	1144	1216	—	—	·783	898 [2]	20	·0240	
·000624	·00006	—	—	—	18	—	1133	1204	—	—	1·715	807	20	·0226	
·00104	·0001	—	—	—	18	—	1126	1197	—	—	2·955	683	20	·0222	[2] Sprung, *Pogg. Annal.* vol. clix. p. 18.
·00208	·0002	—	—	—	18	—	1118	1189	—	—	—	—	—	—	

BARIUM CHLORIDE—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ $BaCl_2$, 104.

			°		°					°			°	
·00624	·0006	—	—	—	18	—	1102	1172	—	—	1·0	883 [3]	20	—
·0104	·001	—	—	—	18	—	1092	1161	—	—	—	—	—	—
·0208	·002	—	—	—	18	—	1074	1142	—	—	·125	963 [4]	20	—
·0624	·006	—	—	—	18	—	1031	1096	—	—	·25	951	20	—
·104	·01	1·0001	15·0	—	18	·0234	1006	1069	—	—	·5	923	20	—
·311	·03	1·0022	15·0	—	18	—	939	998	—	—	1·0	868	20	—
·518	·05	1·0044	15·0	—	18	—	904	961	—	—	—	—	—	—
·784	·076	1·0070	9·6	—	—	—	—	—	·61 [6]	—	·0625	970 [5]	20	—
1·03	·1	1·0094	15·0	—	18	—	861	915	—	—	·125	955	20	—
1·24	·12	1·0112	19·7	—	—	—	—	—	·616	—	·25	926	20	—
4·97	·5	1·0457	15·0	—	18	·0214	725	771	—	—	·5	867	20	—
9·54	1·0	1·0905	15·0	—	18	·0207	658	699	—	—	1·0	760	20	—
10·65	1·13	1·1028	19·0	—	—	—	—	—	·642	—	—	—	—	—
21·6	2·55	1·2277	14·4	—	—	—	—	—	·663	—	—	—	—	—
23·5	2·88	1·2546	7·3	—	—	—	—	—	·664	—	—	—	—	—
—	3·0	1·2655	15·0	—	18	·0193	487	518	—	—	—	—	—	—

[3] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 35.

[5] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

[6] Hittorf, *Pogg. Annal.* vol. cvi. p. 379.

CALCIUM CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CaCl_2$, 55·46.

·434	·078	1·0036	20·0	—	—	—	—	—	·683 [2]	—	—	—	—	—
·718	·13	1·0062	9·0	—	—	—	—	—	·673	—	—	—	—	—
2·71	·5	1·0231	15·0	348·0	18	·0218	696 [1]	740	—	—	—	—	—	—
4·56	·853	1·0382	20·0	—	—	—	—	—	·683	—	3·098	630 [3]	20	·0232
5·307	1·0	1·0451	15·0	633·0	18	·0213	633	673	—	—	7·437	251	20	·0235
10·19	2·0	1·0887	15·0	1083·0	18	·0207	542	576	—	—	9·984	111·4	20	·0309
14·71	3·0	1·1309	15·0	1389·0	18	·0203	463	492	—	—	—	—	—	—
18·93	4·0	1·1718	15·0	1583·0	18	·0201	398	423	—	—	·125	959 [4]	20	—
20·2	4·3	1·1819	20·8	—	—	—	—	—	·727	—	·25	942	20	—
22·88	5·0	1·2119	15·0	1666·0	18	·0202	333	354	—	—	·5	906	20	—
26·6	6·0	1·2510	15·0	1644·0	18	·0206	274	291	—	—	1·0	844	20	—
26·73	6·04	1·2529	9·7	—	—	—	—	—	·749	—	—	—	—	—
29·75	6·91	1·2884	2·8	—	—	—	—	—	·765	—	·125	952 [5]	20	—
30·11	7·0	1·2892	15·0	1541·0	18	·0216	220	234	—	—	·25	922	20	—
32·6	7·73	1·3160	12·4	—	—	—	—	—	·771	—	·5	858	20	—
33·37	8·0	1·3267	15·0	1370·0	18	·0231	171	182	—	—	1·0	751	20	—
36·6	9·0	1·3633	15·0	1177·0	18	·0244	130	138	—	—	—	—	—	—
37·08	9·14	1·3637	20·0	—	—	—	—	—	·78	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 148.

[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 381.

[3] Sprung, *Pogg. Annal.* vol. clix. p. 19.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.

[5] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

·00549	·00099	—	—	—	18	—	990 [6]	1052	—	—	—	—	—	—
·0089	·0016	—	—	—	18	—	970	1031	—	—	—	—	—	—
·015	·0027	—	—	—	18	—	930	989	—	—	—	—	—	—
·017	·00312	—	—	32·6 [7]	18	—	1043	1109	—	—	—	—	—	—
·034	·00625	—	—	63·0	18	—	1008	1071	—	—	—	—	—	—
·069	·0125	—	—	120·2	18	—	972	1033	—	—	—	—	—	—
·138	·025	—	—	228·0	18	—	912	969	—	—	—	—	—	—
·277	·05	1·0017	15·0	430·5	18	—	861	915	—	—	—	—	—	—
·552	·1	1·0043	15·0	809·0	18	—	809	860	—	—	—	—	—	—
1·1	·2	1·0093	15·0	1442·0	18	—	721	766	—	—	—	—	—	—

[6] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

[7] Fitzpatrick, *Phil. Mag.* (5th series), vol. xxvi. p. 377.

MAGNESIUM CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $MgCl_2$, 47·46.

·0046	·000975	—	—	119·9 [1]	25	—	—	1070	—	—	—	—	—	—
·0092	·00195	—	—	115·8	25	—	—	1043	—	—	—	—	—	—
·0185	·0039	—	—	111·6	25	—	—	1010	—	—	·125	1071 [5]	25	—
·037	·00781	—	—	107·2	25	—	—	972	—	—	·25	1046	25	—
·074	·0156	—	—	102·4	25	—	—	930	—	—	·5	999	25	—
·148	·0312	1·0005	15·0	97·3	25	—	—	885	—	—	1·0	957	25	—
·0475	·01	—	—	—	18	·0241	950 [2]	1010	—	—	—	—	—	—
·142	·03	1·0004	15·0	—	18	—	878	932	—	—	·125	950 [6]	20	—
·237	·05	1·0013	15·0	—	18	—	841	894	—	—	·25	915	20	—
·412	·087	1·0035	6·0	—		—	—	—	·678 [4]	—	·5	848	20	—
·473	·1	1·0035	15·0	—	18	—	794	844	—	—	1·0	741	20	—
·773	·164	1·0065	15·0	—	—	—	—	—	·677	—	—	—	—	—
2·327	·5	1·0197	15·0	—	18	·0226	665	706	—	—	—	—	—	—
4·31	·941	1·0366	14·4	—	—	—	—	—	·706	—	—	—	—	—
4·57	1·0	1·0386	15·0	—	18	·0223	593	631	—	—	—	—	—	—
12·81	3·0	1·1114	15·0	—	18	·0224	400	425	—	—	—	—	—	—
20·12	5·0	1·1792	15·0	—	18	·0238	262	288	—	—	—	—	—	—
21·53	5·41	1·1934	15·0	—	—	—	—	—	·779	—	—	—	—	—
28·71	7·67	1·2685	5·6	—	—	—	—	—	·806	—	—	—	—	—
—	10·0	—	—	—	18	·0340	62	66	—	—	—	—	—	—
·0073	·00154	—	—	—	—	—	920 [3]	978	—	—	—	—	—	—
·0091	·00192	—	—	—	—	—	910	967	—	—	—	—	—	—
·0153	·00322	—	—	—	—	—	900	975	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 109.

[2] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 194.

[3] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 383.

[5] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 38.

[6] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

Zinc Chloride.

Equivalent Gramme Molecule, $\frac{1}{2}$ $ZnCl_2$, 67·82.

			°		°					°			°	
·000068	·00001	—	—	—	—	—	1036 [1]	1101	—	—	—	—	—	—
·000136	·00002	—	—	—	—	—	1035	1100	—	—	—	—	—	—
·000407	·00006	—	—	—	—	—	1031	1096	—	—	—	—	—	—
·000678	·0001	—	—	—	—	—	1029	1094	—	—	—	—	—	—
·001356	·0002	—	—	—	—	—	1020	1084	—	—	—	—	—	—
·00407	·0006	—	—	—	—	—	1004	1067	—	—	—	—	—	—
·00678	·001	—	—	—	—	—	994	1057	—	—	1·0	777 [4]	17·6	—
·01356	·002	—	—	—	—	—	979	1040	—	—	—	—	—	—
·0407	·006	—	—	—	—	—	939	998	—	—	—	—	—	—
·0678	·01	—	—	—	—	·0239	915	973	—	—	—	—	—	—
·2034	·03	1·0007	19·5	—	—	—	851	905	—	—	·125	1067 [5]	25·0	—
·3	—	—	—	—	—	—	—	—	·7 [3]	—	·25	1038	25·0	—
·337	·05	1·0023	19·5	—	—	—	817	868	—	—	·5	997	25·0	—
·672	·1	1·0062	19·5	—	—	—	768	816	—	—	1·0	919	25·0	—
3·28	·5	1·0312	19·5	—	—	—	601	639	—	—	—	—	—	—
6·4	1·0	1·0570	19·5	—	—	—	514	546	—	—	—	—	—	—
17·5	3·0	1·1600	19·5	—	—	—	280	298	—	—	—	—	—	—
26·52	—	—	—	—	—	—	—	—	1·08	—	—	—	—	—
26·88	5·0	1·2587	19·5	—	—	—	180	191	—	—	—	—	—	—
45·35	10·0	1·4921	19·5	—	—	—	60	64	—	—	—	—	—	—
·0117	·00173	—	—	—	—	—	910 [2]	967	—	—	—	—	—	—
·023	·0034	—	—	—	—	—	870	924	—	—	—	—	—	—
2·5	·378	1·024	15·0	258 [6]	18	·0213	682	725	—	—	—	—	—	—
5·0	·774	1·048	15·0	452	18	·0192	584	621	—	—	—	—	—	—
10·0	1·617	1·094	15·0	680	18	·0165	421	447	—	—	—	—	—	—
20·0	3·517	1·190	15·0	853	18	·0156	243	258	—	—	—	—	—	—
30·0	5·76	1·299	15·0	866	18	·0172	150	160	—	—	—	—	—	—
40·0	8·41	1·423	15·0	790	18	·0198	94	100	—	—	—	—	—	—
50·0	11·6	1·570	15·0	589	18	·0232	51	54	—	—	—	—	—	—
60·0	15·48	1·746	15·0	345	18	·0307	22	24	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 397.

[4] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[5] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.

[6] Long, *Wied. Annal.* vol. xi. p. 37.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CdCl_2$, 91·37.

·0503	·0055	·9991	18·0	4·6 [1]	18	·0231	835	887	—	—	—	—	—	—	[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 492.
·0999	·01095	·9996	18·0	8·34	18	·0226	761	809	—	—	—	—	—	—	
·20	·02194	1·0004	18·0	14·5	18	·0231	660	702	—	—	—	—	—	—	
·399	·0439	1·0022	18·0	24·7	18	·0227	563	598	—	—	—	—	—	—	
·518	·057	1·0045	10·5	—	—	—	—	—	·708 [3]	—	—	—	—	—	
·599	·066	1·0039	18·0	33·8	18	·0224	512	544	—	—	—	—	—	—	[2] Grotian, *Wied. Annal.* vol. xviii. p. 194.
·769	·0849	1·0057	18·0	41·6	18	·0224	450	478	—	—	·125	1071 [4]	25	—	
·997	·1102	1·0075	18·0	49·2	18	·0222	447	475	—	—	·25	1060	25	—	
1·0	·1105	1·0076	18·0	51·1	18	·0222	—	—	—	—	·5	1028	25	—	
1·002	·1100	—	—	—	—	—	—	—	·725	—	1·0	964	25	—	[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 547.
·849	·0937	1·0062	18·0	45·5 [2]	18	·0224	486	517	—	—	—	—	—	—	
5·01	·574	1·0437	18·0	155·0	18	·0218	270	287	—	—	—	—	—	—	
10·04	1·203	1·0923	18·0	225·0	18	·0217	187	199	—	—	—	—	—	—	[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.
14·79	—	—	—	—	—	—	—	—	·744	—	—	—	—	—	
14·94	1·874	1·1436	18·0	262·0	18	·0218	140	149	—	—	—	—	—	—	
19·8	2·603	1·1984	18·0	277·0	18	·0227	106	112	—	—	—	—	—	—	
22·96	3·12	1·2415	9·5	—	—	—	—	—	·772	—	—	—	—	—	[5] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.
26·60	3·75	1·2891	9·5	—	—	—	—	—	·779	—	—	—	—	—	
29·97	4·373	1·3302	18·0	262·0	18	·0252	60	64	—	—	—	—	—	—	
33·53	5·10	1·3899	7·0	—	—	—	—	—	·873	—	—	—	—	—	
40·13	6·558	1·4899	18·0	204·0	18	·0291	31	33	—	—	—	—	—	—	
43·76	7·50	1·5657	6·8	—	—	—	—	—	1·014	—	—	—	—	—	
44·06	7·56	1·5681	9·8	—	—	—	—	—	1·016	—	—	—	—	—	
49·51	9·067	1·6697	18·0	131·0	18	·0353	14	15	—	—	—	—	—	—	
·00649	·00071	—	—	—	18	·0241	960 [5]	1020	—	—	—	—	—	—	
·01097	·0012	—	—	—	18	·0244	920	978	—	—	—	—	—	—	
·0193	·00211	—	—	—	18	·0236	870	925	—	—	—	—	—	—	
·0471	·00515	—	—	—	18	·0237	780	829	—	—	—	—	—	—	

CUPRIC CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CuCl_2$, 67·07.

·0063	·00094	—	—	—	18	—	930 [1]	989	—	—	—	—	—	—	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.
·0107	·0016	—	—	—	18	—	900	957	—	—	·125	1064 [2]	25	—	
·0201	·003	—	—	—	18	—	870	925	—	—	·25	1044	25	—	[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 37.
·0396	·0059	—	—	—	18	—	860	915	—	—	·5	996	25	—	
·0885	·0132	—	—	—	18	—	750	797	—	—	1·0	907	25	—	
—															

FERROUS CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $FeCl_2$, 63·32.

			°		°					°			°		
·0064	·00101	—	—	—	18	—	710 [1]	754	—	—	—	—	—	—	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.
01583	·0025	—	—	—	18	—	700	744	—	—	—	—	—	—	
·02406	·0038	—	—	—	18	—	680	723	—	—	—	—	—	—	

NICKEL CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $NiCl_2$, 64·67.

·00789	·00122	—	—	—	18	·0245	730 [1]	776	—	—	—	—	—	—	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.
·00963	·00149	—	—	—	18	·0240	730	776	—	—	·125	1070 [2]	25	—	[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 39.
·01196	·00185	—	—	—	18	—	740	787	—	—	·25	1046	25	—	
·01875	·0029	—	—	—	18	·0245	730	776	—	—	·5	996	25	—	
—	—	—	—	—	—	—	—	—	—	—	1·0	907	25	—	

MANGANESE CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $MnCl_2$, 62·87.

·522	·083	1·0045	9·0	—	—	—	—	—	·682 [2]	—	—	—	—	—	[1] Long, *Wied. Annal.* vol. xi. p. 37.
5·0	·831	1·0456	15·0	492 [1]	18	·0216	592	629	—	—	—	—	—	—	[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 383.
10·0	1·733	1·0895	15·0	790	18	·0206	456	485	—	—	·125	1068 [3]	25	—	[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 37.
15·0	2·715	1·1378	15·0	987	18	·0202	363	386	—	—	·25	1043	25	—	
20·0	3·785	1·1900	15·0	1061	18	·0206	280	298	—	—	·5	995	25	—	
23·22	4·524	1·2275	6·6	—	—	—	—	—	·758	—	1·0	904	25	—	
25·0	4·960	1·2472	15·0	1020	18	·0203	206	219	—	—	—	—	—	—	
28·0	5·710	1·2828	15·0	950	18	·0208	166	176	—	—	—	—	—	—	

ALUMINIUM CHLORIDE.

Equivalent Gramme Molecule, $\frac{1}{6}$ Al_2Cl_6, 44·37.

·00697	·00157	—	—	—	18	—	830 [1]	882	—	—	—	—	—	—	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.
·00887	·002	—	—	—	18	—	800	850	—	—	—	—	—	—	[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 391.
·01642	·0037	—	—	—	18	—	806	857	—	—	—	—	—	—	
4·22	—	—	—	—	—	—	—	—	·714 [2]	—	—	—	—	—	

Ferric Chloride.

Equivalent Gramme Molecule, $\frac{1}{6}Fe_2Cl_6$, 54.

·0054	·0010	—	—	—	18	—	2360[1]	2509	—	—	—	—	—	—
·0108	·0020	—	—	—	18	—	1660	1765	—	—	—	—	—	—
·0130	·0024	—	—	—	18	—	1510	1605	—	—	—	—	—	—
·0184	·0034	—	—	—	18	—	1460	1552	—	—	—	—	—	—
·0286	·0053	—	—	—	18	—	1290	1371	—	—	—	—	—	—
·0324	·0060	—	—	—	18	—	1300	1382	—	—	—	—	—	—
·0168	·00312	—	—	—	18	—	—	1617[2]	—	—	—	—	—	—
·0337	·00625	—	—	—	18	—	—	1496	—	—	—	—	—	—
·0674	·0125	—	—	—	18	—	—	1356	—	—	—	—	—	—
·1348	·025	—	—	—	18	—	—	1211	—	—	—	—	—	—
·2696	·05	—	—	—	18	—	—	1053	—	—	—	—	—	—
·539	·1	—	—	—	18	—	—	908	—	—	—	—	—	—
1·078	·2	—	—	—	18	—	—	741	—	—	—	—	—	—
3·81	—	—	—	—	—	—	—	—	·6[3]	—	—	—	—	—
32·51	—	—	—	—	—	—	—	—	·746	—	—	—	—	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx.

[2] Fitzpatrick, *Phil. Mag.* vol. xxiv. p. 377.

[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 389.

Hydrobromic Acid.

Equivalent Gramme Molecule, HBr, 80·75.

·00195	·000244	—	—	87·8[1]	25	—	—	3559	—	—	—	—	—	—
·0039	·000488	—	—	88·9	25	—	—	3612	—	—	—	—	—	—
·0078	·000976	—	—	89·7	25	—	—	3636	—	—	—	—	—	—
·0156	·00195	—	—	89·8	25	—	—	3644	—	—	—	—	—	—
·0312	·0039	—	—	89·6	25	—	—	3640	—	—	—	—	—	—
·0625	·0078	—	—	89·4	25	—	—	3632	—	—	—	—	—	—
·125	·0156	—	—	88·9	25	—	—	3612	—	—	—	—	—	—
·25	·0312	—	—	87·9	25	—	—	3571	—	—	—	—	—	—
·502	·0625	1·004	14	86·6	25	—	—	3519	—	—	—	—	—	—
1·0	·125	1·007	14	85·1	25	—	—	3458	—	—	—	—	—	—
2·0	·25	1·014	14	83·4	25	—	—	3389	—	—	—	—	—	—
3·92	·5	1·027	14	80·4	25	·0153	—	3267	—	—	—	—	—	—
10·36	—	—	—	—	—	—	—	—	·178[2]	—	—	—	—	—

[1] Ostwald, *Journ. für Chemie*, vol. xxxi. p. 438.

[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 399.

POTASSIUM BROMIDE.

Equivalent Gramme Molecule, KBr, 118·79.

			°		°					°			°	
·851	·072	1·0063	7·0	—	—	—	—	—	·514 [2]	—	—	—	—	—
—	·5	—	—	497 [1]	18	·0205	994	1057	—	—	—	—	—	—
—	1·0	—	—	960	18	·0193	960	1020	—	—	1·309	1013 [3]	20	·0217
—	1·5	—	—	1404	18	·0184	936	995	—	—	2·321	1028	20	·0203
—	2·0	—	—	1832	18	·0177	916	974	—	—	3·824	999	20	·0179
—	2·5	—	—	2243	18	·0171	897	954	—	—	—	—	—	—
—	3·0	—	—	2623	18	·0166	874	929	—	—	—	—	—	—
29·7	3·15	1·261	12·2	—	—	—	—	—	·528	—	—	—	—	—
—	3·5	—	—	2977	18	·0160	850	904	—	—	—	—	—	—
—	4·0	—	—	3294	18	·0156	824	876	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.

[2] Hittorf, *Pogg. Annal.* vol. xcviii. p. 27.

[3] Sprung, *Pogg. Annal.* vol. clix. p. 11.

CADMIUM BROMIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CdBr_2$, 135·75.

·0324	·002386	·9990	18	2·15 [1]	18	·0235	899	956	—	—	—	—	—	—
·0748	·005517	·99935	18	4·37	18	·0237	792	842	—	—	—	—	—	—
·154	·01134	1·00002	18	7·84	18	·0239	691	735	—	—	—	—	—	—
·253	·01867	1·0010	18	11·6	18	·0237	623	662	—	—	—	—	—	—
·506	·03743	1·0031	18	19·8	18	·0238	529	562	—	—	—	—	—	—
1·013	·07517	1·0075	18	33·3	18	·0233	443	471	—	—	—	—	—	—
1·01	·0751	1·0073	18	33·4 [2]	18	·0232	445	473	—	—	—	—	—	—
5·07	·390	1·0437	18	101·0	18	·0225	259	275	—	—	—	—	—	—
10·10	·813	1·0916	18	152·0	18	·0232	187	199	—	—	—	—	—	—
20·11	1·781	1·2004	18	219·0	18	·0239	123	131	—	—	—	—	—	—
29·95	2·936	1·3288	18	253·0	18	·0258	86	91·4	—	—	—	—	—	—
42·99	4·904	1·5464	18	242·0	18	·0288	49	52	—	—	—	—	—	—

[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 493.

[2] Grotian, *Wied. Annal.* vol. xviii. p. 194.

HYDRIODIC ACID.

Equivalent Gramme Molecule, HI, 127·53.

·0031	·000244	—	—	87·8 [1]	25	—	—	3567	—	—	—	—	—	—
·0062	·000488	—	—	89·0	25	—	—	3616	—	—	—	—	—	—
·0123	·000976	—	—	89·3	25	—	—	3628	—	—	—	—	—	—
·0247	·00195	—	—	89·7	25	—	—	3644	—	—	—	—	—	—
·0495	·0039	—	—	89·7	25	—	—	3644	—	—	—	—	—	—

[1] Ostwald, *Journ. für Chemie*, vol. xxxi. p. 438.

·099	·0078	—	—	89·4	25	—	—	3632	—	—	—	—	—	—
·198	·0156	—	—	88·7	25	—	—	3608	—	—	—	—	—	—
·397	·0312	—	—	87·6	25	—	—	3559	—	—	—	—	—	—
·792	·0625	1·0058	13·5	86·4	25	—	—	3511	—	—	—	—	—	—
·844	—	—	—	—	25	—	—	—	·258 [2]	—	—	—	—	—
1·576	·125	1·0117	13·5	84·9	25	·0158	—	3450	—	—	—	—	—	—
3·11	·25	1·0230	13·5	83·2	25	—	—	3381	—	—	—	—	—	—
6·1	·5	1·0453	13·5	80·4	25	—	—	3267	—	—	—	—	—	—
17·17	—	—	—	—	—	—	—	—	·201	—	—	—	—	—

[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 401.

POTASSIUM IODIDE.

Equivalent Gramme Molecule, KI, 165·9.

·017	·000976	—	—	143·1 [1]	25	—	—	1319	—	—	—	—	—	—
·034	·00195	—	—	139·1	25	—	—	1282	—	—	—	—	—	—
·067	·0039	—	—	136·1	25	—	—	1254	—	—	—	—	—	—
·134	·0078	—	—	132·9	25	—	—	1225	—	—	—	—	—	—
·269	·0156	—	—	129·3	25	—	—	1192	—	—	—	—	—	—
·518	·0312	—	—	125·4	25	—	—	1156	—	—	—	—	—	—
·000166	·00001	—	—	—	18	—	1207 [2]	1283	—	—	—	—	—	—
·000332	·00002	—	—	—	18	—	1216	1293	—	—	—	—	—	—
·000995	·00006	—	—	—	18	—	1216	1293	—	—	—	—	—	—
·00166	·0001	—	—	—	18	—	1216	1293	—	—	—	—	—	—
·00332	·0002	—	—	—	18	—	1214	1291	—	—	—	—	—	—
·00996	·0006	—	—	—	18	—	1209	1285	—	—	·541	1009 [4]	20	·0242
·0166	·001	—	—	—	18	—	1203	1279	—	—	1·171	1057	20	·0219
·0332	·002	—	—	—	18	—	1197	1273	—	—	2·610	1082	20	·0190
·0996	·006	—	—	—	18	—	1176	1250	—	—	4·119	1046	20	·0170
·166	·01	—	—	—	18	·0219	1161	1234	—	—	5·257	986	20	·0158
·495	·03	—	—	—	18	—	1123	1194	—	—	—	—	—	—
·8255	·05	1·0048	19·5	—	18	—	1102	1172	—	—	—	—	—	—
1·640	·1	1·0112	19·5	—	18	—	1069	1136	—	—	1·0	1066 [5]	20	—
7·823	·5	1·0603	19·5	—	18	·0203	997	1060	—	—	—	—	—	—
10·57	·705	1·1081	12·0	—	—	—	—	—	·511 [3]	—	—	—	—	—
14·84	1·0	1·1180	19·5	—	18	·0194	968	1029	—	—	—	—	—	—
26·86	2·01	1·2414	11·0	—	—	—	—	—	·512	—	—	—	—	—
36·8	3·0	1·3530	19·5	—	18	·0156	900	957	—	—	—	—	—	—
52·3	5·0	1·5860	19·5	—	18	·0142	770	819	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie,* vol. i. p. 85.

[2] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[3] Hittorf, *Pogg. Annal.* vol. xcviii. p. 29.

[4] Sprung, *Pogg. Annal.* vol. clix. p. 1.

[5] Arrhenius, *Zeitschrift für Physik. Chemie,* vol. i. p. 295.

AMMONIUM IODIDE.

Equivalent Gramme Molecule, NH_4I, 144·84.

10·0	·735	1·0652	18°	722[1]	18°	·0202	982	1044	—	—°	—	—	—°	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.
20·0	1·574	1·1397	18	1494	18	·0193	949	1009	—	—	—	—	—	—	
30·0	2·54	1·2260	18	2318	18	·0180	912	969	—	—	—	—	—	—	
40·0	3·663	1·3260	18	3166	18	·0167	867	922	—	—	—	—	—	—	
50·0	4·98	1·4415	18	3917	18	·0154	786	835	—	—	—	—	—	—	

SODIUM IODIDE.

Equivalent Gramme Molecule, NaI, 149·84.

5·0	·346	1·0374	18	279[1]	18	·0222	806	857	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.
10·0	·721	1·0803	18	543	18	·0216	753	801	—	—	—	—	—	—	
20·0	1·567	1·1735	18	1069	18	·0204	682	725	—	—	—	—	—	—	
30·0	2·57	1·2836	18	1545	18	·0198	600	638	—	—	—	—	—	—	
40·0	3·77	1·4127	18	1972	18	·0199	523	556	—	—	—	—	—	—	

LITHIUM IODIDE.

Equivalent Gramme Molecule, LiI, 133·82.

5·0	·387	1·0361	18	277[1]	18	·0219	716	761	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.
10·0	·804	1·0756	18	536	18	·0216	666	708	—	—	—	—	—	—	
15·0	1·253	1·1180	18	783	18	·0212	625	665	—	—	—	—	—	—	
20·0	1·740	1·1643	18	1023	18	·0207	588	625	—	—	—	—	—	—	
25·0	2·267	1·2138	18	1258	18	·0203	555	590	—	—	—	—	—	—	

CADMIUM IODIDE.

Equivalent Gramme Molecule $\frac{1}{2}$ CdI_2, 182·53.

·0429	·00235	·9991	18·0	1·95[1]	18	·0257	829	881	—	—	—	—	—	—	[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 493.
·1	·0055	·9996	18·0	3·83	18	·0261	696	740	—	—	—	—	—	—	
·204	·0112	1·0005	18·0	6·6	18	·0262	589	626	—	—	—	—	—	—	
·399	·0220	1·0021	18·0	10·7	18	·0264	486	517	—	—	—	—	—	—	[2] Grotian, *Wied. Annal.* vol. xviii. p. 194.
·6	·0330	1·0038	18·0	14·1	18	·0266	427	454	·613[3]	—	—	—	—	—	
·8	·0441	1·0056	18·0	17·0	18	·0270	386	410	—	—	—	—	—	—	
1·0	·0552	1·0072	18·0	19·7	18	·0271	356	378	—	—	—	—	—	—	[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 543.
1·017	·0562	1·0073	18·0	19·7[2]	18	·0286	350	372	—	—	—	—	—	—	
1·41	—	—	—	—	—	—	—	—	·642	—	—	—	—	—	

4·87	·278	1·0413	18·0	55·5	18	·0261	200	213	—	—	—	—	—	—	
5·23	·3	1·0456	11·2	—	—	—	—	—	·931	—	—	—	—	—	
10·03	·599	1·0885	18·0	96·6	18	·0248	161	171	—	—	—	—	—	—	
14·67	·913	1·1354	18·0	132·0	18	·0242	144	153	—	—	—	—	—	—	
19·0	1·230	1·1854	11·8	—	—	—	—	—	1·14	—	—	—	—	—	
19·54	1·274	1·1890	18·0	169·0	18	·0240	132	140	—	—	—	—	—	—	
24·75	1·700	1·2551	11·0	—	—	—	—	—	1·192	—	—	—	—	—	
29·6	2·138	1·3171	18·0	234·0	18	·0244	101	107	—	—	—	—	—	—	
35·32	—	—	—	—	—	—	—	—	1·258	—	—	—	—	—	
40·03	3·254	1·4821	18·0	281·0	18	·0254	86	91	—	—	—	—	—	—	
44·13	3·770	1·5576	18·0	290·0	18	·0258	77	82	—	—	—	—	—	—	
47·5	—	—	18·0	293·0	18	·0263	—	—	—	—	—	—	—	—	

POTASSIUM CADMIUM IODIDE.

Equivalent Gramme Molecule, $\frac{1}{2}$ K_2CdI_4, 347·43.

·0328	·00094	·99895	18	1·9 [1]	18	·0226	2016	2143	—	—	—	—	—	—	[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 493.
·0596	·00171	·99921	18	3·32	18	·0231	1935	2057	—	—	—	—	—	—	
·0804	·00231	·99938	18	4·32	18	·0228	1869	1987	—	—	—	—	—	—	
·10	·00287	·99945	18	5·26	18	·0229	1831	1946	—	—	—	—	—	—	
·25	·00719	1·0007	18	11·8	18	·0233	1645	1748	—	—	—	—	—	—	
·50	·01441	1·0027	18	21·6	18	·0231	1498	1592	—	—	—	—	—	—	[2] Grotian, *Wied. Annal.* vol. xviii. p. 194.
1·003	·02923	1·0067	18	38·5	18	·0234	1317	1400	—	—	—	—	—	—	
1·674	—	—	—	—	—	—	—	—	·65 [3]	—	—	—	—	—	
1·006	·0291	1·0065	18	38·3 [2]	18	·0235	1309	1391	—	—	—	—	—	—	[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 527.
5·04	·151	1·0387	18	148·0	18	·0227	980	1042	—	—	—	—	—	—	
10·14	·315	1·0821	18	278·0	18	·0224	882	938	—	—	—	—	—	—	
15·11	·490	1·1280	18	408·0	18	·0218	833	885	—	—	—	—	—	—	
25·25	·896	1·2338	18	689·0	18	·0214	769	817	·79	—	—	—	—	—	
30·33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
34·96	1·362	1·3552	18	986·0	18	·0207	724	770	—	—	—	—	—	—	
45·12	1·957	1·5086	18	1319·0	18	·0198	674	716	—	—	—	—	—	—	

HYDROFLUORIC ACID.

Equivalent Gramme Molecule, HF, 20·1.

·000488	·000244	—	—	69·42 [1]	25	—	—	3134 [2]	—	—	—	—	—	—	[1] Ostwald, *Journ. für Chemie*, vol. xxxii. p. 303.
·000976	·000488	—	—	59·56	25	—	—	2689	—	—	—	—	—	—	
·00195	·000976	—	—	49·49	25	—	—	2235	—	—	—	—	—	—	
·0039	·00195	—	—	39·11	25	—	—	1765	—	—	—	—	—	—	[2] At 25°.

Hydrofluoric Acid—*continued*.

Equivalent Gramme Molecule, HF, 20·1.

·0078	·0039	—	° —	30·30	25°	—	—	1368	—	° —	—	—	° —	—	
·0156	·0078	—	—	23·11	25	—	—	1043	—	—	—	—	—	—	
·0312	·0156	—	—	17·38	25	—	—	786	—	—	—	—	—	—	
·0625	·0312	—	—	13·14	25	—	—	594	—	—	—	—	—	—	
·125	·0625	—	—	10·00	25	—	—	451	—	—	—	—	—	—	
·25	·125	—	—	7·89	25	—	—	356	—	—	—	—	—	—	
·5	·25	—	—	6·54	25	—	—	296	—	—	—	—	—	—	

Potassium Fluoride.

Equivalent Gramme Molecule, KF, 58·14.

—	·5	—	—	367 [1]	18	—	734	780	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.
—	1·0	—	—	676	18	·0214	676	718	—	—	—	—	—	—	
—	2·0	—	—	1196	18	·0217	598	636	—	—	—	—	—	—	
—	3·0	—	—	1609	18	·0219	536	570	—	—	—	—	—	—	
—	4·0	—	—	1936	18	·0220	484	514	—	—	—	—	—	—	
—	5·0	—	—	2182	18	·0222	436	463	—	—	—	—	—	—	
—	6·0	—	—	2338	18	·0226	390	414	—	—	—	—	—	—	
—	7·0	—	—	2416	18	·0232	345	366	—	—	—	—	—	—	
—	8·0	—	—	2422	18	·0238	303	322	—	—	—	—	—	—	
—	9·0	—	—	2385	18	·0248	265	282	—	—	—	—	—	—	
—	10·0	—	—	2303	18	·0260	230	244	—	—	—	—	—	—	

Nitric Acid.

Equivalent Gramme Molecule, HNO_3, 63·04.

·000063	·00001	—	—	—	18	—	1144 [1]	1213	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.
·000126	·00002	—	—	—	18	—	1904	2024	—	—	—	—	—	—	
·00038	·00006	—	—	—	18	—	2863	3043	—	—	—	—	—	—	
·00063	·0001	—	—	—	18	—	3088	3282	—	—	—	—	—	—	
·00126	·0002	—	—	—	18	—	3285	3492	—	—	—	—	—	—	
·00378	·0006	—	—	—	18	—	3408	3622	—	—	—	—	—	—	
·0063	·001	—	—	—	18	—	3427	3643	—	—	—	—	—	—	
·0126	·002	—	—	—	18	—	3448	3665	—	—	—	—	—	—	
·0378	·006	—	—	—	18	—	3421	3636	—	—	—	—	—	—	
·063	·01	—	—	—	18	·0162	3395	3609	—	—	—	—	—	—	

·189	·03	—	—	—	18	—	3328	3537	—	—	1·02	950[2]	20	·0227
·315	·05	—	—	—	18	—	3289	3497	—	—	2·11	921	20	·0211
·63	·1	1·0034	15	—	18	—	3225	3428	—	—	3·28	874	20	·0200
3·09	·5	1·0185	15	—	18	—	2991	3179	—	—	5·865	788	20	·0184
6·09	1·0	1·0354	15	—	18	—	2770	2944	—	—	7·24	669	20	·0181
17·17	3·0	1·1010	15	—	18	—	2070	2200	—	—	—	—	—	—
22·0	5·0	1·1660	15	—	18	—	1470	1562	—	—	—	—	—	—
48·26	10·0	1·3061	15	—	18	—	610	648	—	—	—	—	—	—
·00075	·000121	—	—	83·9[3]	25	—	—	3234	—	—	—	—	—	—
·0015	·000243	—	—	86·7	25	—	—	3432	—	—	—	—	—	—
·0030	·000487	—	—	88·2	25	—	—	3537	—	—	—	—	—	—
·0061	·000975	—	—	89·0	25	—	—	3585	—	—	—	—	—	—
·0122	·00195	—	—	88·9	25	—	—	3591	—	—	—	—	—	—
·0245	·0039	—	—	88·5	25	—	—	3580	—	—	—	—	—	—
·049	·0078	—	—	88·4	25	—	—	3574	—	—	—	—	—	—
·098	·0156	—	—	87·5	25	—	—	3544	—	—	—	—	—	—
·197	·0312	—	—	86·2	25	—	—	3500	—	—	—	—	—	—
·393	·0625	1·0017	15	84·9	25	—	—	3443	—	—	—	—	—	—
·784	·125	1·0044	15	82·7	25	—	—	3358	—	—	—	—	—	—
1·56	·25	1·0090	15	80·2	25	—	—	3261	—	—	—	—	—	—
3·09	·5	1·0185	15	77·9	25	—	—	3159	—	—	—	—	—	—
·396	·063	1·0019	15	20·5[4]	18	—	3254	3459	—	—	—	—	—	—
785	·126	1·0046	15	40·3	18	—	3200	3401	—	—	—	—	—	—
1·57	·252	1·0094	15	78·3	18	—	3103	3298	—	—	—	—	—	—
3·12	·504	1·0188	15	150·0	18	—	2953	3139	—	—	—	—	—	—

[2] Grotian, *Pogg. Annal.* vol. clx. p. 262.

[3] Ostwald, *Journ. für Chemie*, vol. xxxi. p. 439.

[4] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

POTASSIUM NITRATE.

Equivalent Gramme Molecule, KNO_3, 101·17.

·000101	·00001	—	—	—	18	—	1215[1]	1292	—	—	—	—	—	—
·000202	·00002	—	—	—	18	—	1198	1274	—	—	—	—	—	—
·000607	·00006	—	—	—	18	—	1220	1297	—	—	—	—	—	—
·00101	·0001	—	—	—	18	—	1207	1283	—	—	·649	993[2]	20	·0246
·00202	·0002	—	—	—	18	—	1199	1275	—	—	1·3	1008	20	·0225
·00607	·0006	—	—	—	18	—	1190	1265	—	—	1·943	988	20	·0214
·0101	·001	—	—	—	18	—	1180	1255	—	—	—	—	—	—
·0202	·002	—	—	—	18	—	1173	1247	—	—	1·0	1018[3]	20	—
·0607	·006	—	—	—	18	—	140	1212	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 12.

[3] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i p. 295.

POTASSIUM NITRATE—*continued.*

Equivalent Gramme Molecule, KNO_3, 101·17.

			°		°					°			°	
·101	·01	·99988	15·0	—	18	·0216	1122	1193	—	—	·125	981[6]	20	—
·303	·03	1·0013	15·0	—	18	—	1067	1134	—	—	·25	986	20	—
·504	·05	1·0028	15·0	—	18	—	1037	1102	—	—	·5	991	20	—
1·005	·1	1·0064	15·0	—	18	—	983	1045	—	—	1·0	1003	20	—
1·06	·105	1·0068	8·0	—	—	—	—	—	·497[5]	—	—	—	—	—
3·08	·31	1·0201	7·0	—	—	—	—	—	·494	—	—	—	—	—
4·9	·5	1·0314	15·0	—	18	·0209	839	892	—	—	·125	987[7]	20	—
9·4	·99	1·0620	11·4	—	—	—	—	—	·487	—	·25	987	20	—
9·52	1·0	1·0621	15·0	—	18	·0206	752	799	—	—	·5	989	20	—
17·8	2·1	1·1290	12·0	—	—	—	—	—	·479	—	1·0	994	20	—
—	3·0	—	—	—	18	·0188	572	608	—	—	—	—	—	—
·0099	·000976	—	—	135·9[4]	25	—	—	1255	—	—	—	—	—	—
·0197	·00195	—	—	132·6	25	—	—	1224	—	—	—	—	—	—
·0395	·0039	—	—	129·2	25	—	—	1193	—	—	—	—	—	—
·079	·0078	—	—	125·7	25	—	—	1161	—	—	—	—	—	—
·158	·0156	—	—	121·6	25	—	—	1123	—	—	—	—	—	—
·316	·0312	—	—	117·2	25	—	—	1086	—	—	—	—	—	—
·63	·0625	1·0037	15·0	61·9[8]	18	—	991	1053	—	—	—	—	—	—
1·254	·125	1·0080	15·0	117·8	18	—	942	1001	—	—	—	—	—	—
2·49	·25	1·0159	15·0	221·0	18	—	882	937	—	—	—	—	—	—
4·9	·5	1·0314	15·0	408·0	18	—	816	867	—	—	—	—	—	—

[4] Ostwald, *Zeitschrift für Physik. Chemie,* vol. i. p. 85.

[5] Hittorf, *Pogg. Annal.* vol. ciii. p. 41.

[6] Wagner, *Zeitschrift für Physik. Chemie,* vol. v. p. 37.

[7] Mutzel, *Wied. Annal.* vol. xliii. p. 26.

[8] Lenz, *Mémoire de l'Acad. de St. Pétersbourg,* vol. xxvi.

AMMONIUM NITRATE.

Equivalent Gramme Molecule, NH_4NO_3, 79·9.

—	·5	—	—	442·0[1]	18	·0206	884	939	—	—	—	—	—	—
—	1·0	—	—	831·0	18	·0199	831	883	—	—	·767[2]	1011	20	·0236
—	2·0	—	—	1507·0	18	·0187	754	801	—	—	1·606	1018	20	·0223
—	3·0	—	—	2082·0	18	·0178	694	737	—	—	3·8	1000	20	·0167
—	4·0	—	—	2561·0	18	·0170	640	680	—	—	5·46	927	20	·0169
—	5·0	—	—	2929·0	18	·0165	586	623	—	—	7·71	743	20	·0173
—	6·0	—	—	3190·0	18	·0161	532	565	—	—	—	—	—	—
—	7·0	—	—	3351·0	18	·0158	479	505	—	—	—	—	—	—
—	8·0	—	—	3419·0	18	·0157	427	454	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 10.

—	·0625	—	—	62·9 [3]	18	—	1006	1069	—	—	—	—	—	—
—	·125	—	—	120·1	18	—	961	1021	—	—	—	—	—	—
—	·25	—	—	227·0	18	—	908	965	—	—	—	—	—	—
—	·5	—	—	432·7	18	—	865	919	—	—	—	—	—	—

[3] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

SODIUM NITRATE.

Equivalent Gramme Molecule, $NaNO_3$, 85·08.

·000085	·00001	—	—	—	18	—	975 [1]	1036	—	—	—	—	—	—
·00017	·00002	—	—	—	18	—	972	1033	—	—	—	—	—	—
·00051	·00006	—	—	—	18	—	970	1031	—	—	·895	931 [5]	20	·0240
·00085	·0001	—	—	—	18	—	975	1036	—	—	1·58	872	20	·0241
·0017	·0002	—	—	—	18	—	966	1027	—	—	2·422	801	20	·0234
·0051	·0006	—	—	—	18	—	956	1016	—	—	4·614	583	20	·0245
·0085	·001	—	—	—	18	—	952	1013	—	—	—	—	—	—
·017	·002	—	—	—	18	—	942	1001	—	—	1·0	929 [6]	20	—
·051	·006	—	—	—	18	—	921	979	—	—	—	—	—	—
·085	·01	—	—	—	18	·0226	907	964	—	—	·125	978 [7]	20	—
·255	·03	1·0004	20·2	—	18	—	877	932	—	—	·25	968	20	—
·424	·05	1·0018	20·2	—	18	—	855	909	—	—	·5	945	20	—
·77	·091	1·0052	13·0	—	—	—	—	—	·613 [4]	—	1·0	893	20	—
·846	·1	1·0053	20·2	—	18	—	817	868	—	—	—	—	—	—
1·057	·125	1·0074	10·0	—	—	—	—	—	·615	—	—	—	—	—
1·72	·204	1·0118	12·0	—	—	—	—	—	·613	—	—	—	—	—
2·8	·335	1·0195	12·0	—	—	—	—	—	·614	—	—	—	—	—
4·14	·5	1·0273	20·2	—	18	·0223	694	738	—	—	—	—	—	—
8·07	1·0	1·0542	20·2	—	18	·0219	617	656	—	—	—	—	—	—
22·04	3·0	1·1581	20·2	—	18	·0216	430	457	—	—	—	—	—	—
25·0	3·5	1·1904	9·2	—	—	—	—	—	·600	—	—	—	—	—
·53	·0625	1·0026	20·2	52·1 [2]	18	—	834	886	—	—	—	—	—	—
1·056	·125	1·0067	20·2	98·4	18	—	787	836	—	—	—	—	—	—
2·1	·25	1·0137	20·2	184·8	18	—	739	785	—	—	—	—	—	—
4·14	·5	1·0273	20·2	340·0	18	—	680	725	—	—	—	—	—	—
·0083	·000976	—	—	113·7 [3]	25	—	—	1043	—	—	—	—	—	—
·0166	·00195	—	—	111·2	25	—	—	1020	—	—	—	—	—	—
·0331	·0039	—	—	108·5	25	—	—	996	—	—	—	—	—	—
·0662	·0078	—	—	105·6	25	—	—	969	—	—	—	—	—	—
·1325	·0156	—	—	102·4	25	—	—	940	—	—	—	—	—	—
·265	·0312	1·0004	20·2	99·0	25	—	—	909	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 80.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 377.

[5] Sprung, *Pogg. Annal.* vol. clix. p. 14.

[6] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[7] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

LITHIUM NITRATE.

Equivalent Gramme Molecule, $LiNO_3$, 68·9.

			°		°					°			°	
·0067	·000976	—	—	105·1[1]	25	—	—	962	—	—	—	—	—	—
·0134	·00195	—	—	102·0	25	—	—	934	—	—	—	—	—	—
·0268	·0039	—	—	99·0	25	—	—	906	—	—	—	—	—	—
·0535	·0078	—	—	96·1	25	—	—	880	—	—	—	—	—	—
·107	·0156	—	—	92·6	25	—	—	848	—	—	—	—	—	—
·214	·0312	—	—	89·6	25	—	—	820	—	—	—	—	—	—
·0134	·00195	—	—	1·65[2]	18	—	844	900	—	—	—	—	—	—
·0268	·0039	—	—	3·26	18	—	839	889	—	—	—	—	—	—
·0535	·0078	—	—	6·45	18	—	825	880	—	—	—	—	—	—
·107	·0156	—	—	12·6	18	—	810	856	—	—	—	—	—	—
·214	·0312	—	—	24·2	18	—	774	827	—	—	—	—	—	—
·428	·0625	—	—	46·5	18	—	744	790	—	—	—	—	—	—
—	·125	—	—	88·5	18	—	708	752	—	—	—	—	—	—
—	·25	—	—	166·0	18	—	664	707	—	—	—	—	—	—
—	·5	—	—	303·0	18	—	606	645	—	—	—	—	—	—
—	1·0	—	—	532·0	18	—	532	550	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 83.

[2] Fitzpatrick, *Phil. Mag.* (5th series), vol. xxiv. p. 377.

SILVER NITRATE.

Equivalent Gramme Molecule, $AgNO_3$, 169·9.

·00017	·00001	—	—	—	18	—	1080[1]	1148	—	—	—	—	—	—
·00034	·00002	—	—	—	18	—	1073	1141	—	—	—	—	—	—
·00102	·00006	—	—	—	18	—	1077	1145	—	—	—	—	—	—
·0017	·0001	—	—	—	18	—	1078	1146	—	—	—	—	—	—
·0034	·0002	—	—	—	18	—	1077	1145	—	—	—	—	—	—
·0102	·0006	—	—	—	18	—	1069	1136	—	—	—	—	—	—
·017	·001	—	—	—	18	—	1068	1135	—	—	·125	1093[3]	25	—
·034	·002	—	—	—	18	—	1057	1124	—	—	·25	1086	25	—
·102	·006	—	—	—	18	—	1033	1098	—	—	·5	1071	25	—
·17	·01	—	—	—	18	·0221	1017	1081	—	—	1·0	1033	25	—
·403	—	1·0044	9·6	—	—	—	—	—	·524[2]	9·6	—	—	—	—
·507	·03	—	—	—	18	—	966	1027	—	—	—	—	—	—
·842	·05	1·0070	18·0	—	18	—	936	995	—	—	—	—	—	—
·947	—	1·0076	18·6	—	—	—	—	—	·526	18·6	—	—	—	—
1·657	·1	1·0131	18·0	—	18	—	886	942	—	—	—	—	—	—
1·98	—	1·0166	18·5	—	—	—	—	—	·526	18·5	—	—	—	—
4·06	—	1·0343	18·4	—	—	—	—	—	·527	18·4	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Hittorf, *Pogg. Annal.* vol. lxxxix. p. 203.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.

7·927	·5	1·0693	18·0	—	18	·0218	728	774	—	—	—	—	—	—
8·772	—	1·0774	18·8	—	—	—	—	—	·510	18·8	—	—	—	—
14·91	1·0	1·1395	18·0	—	18	·0216	635	675	—	—	—	—	—	—
16·18	—	1·1534	18·4	—	—	—	—	—	·495	18·4	—	—	—	—
26·81	—	1·2788	19·2	—	—	—	—	—	·478	19·0	—	—	—	—
28·73	—	1·3079	11·1	—	—	—	—	—	·468	11·2	—	—	—	—
36·11	3·0	1·4120	18·0	—	18	·0207	448	476	—	—	—	—	—	—
50·44	5·0	1·6843	18·0	—	18	·0206	351	373	—	—	—	—	—	—
·0136	·0008	—	—	1232 [4]	25	—	—	1134	—	—	—	—	—	—
·0255	·0015	—	—	1221	25	—	—	1124	—	—	—	—	—	—
·051	·003	—	—	1206	25	—	—	1110	—	—	—	—	—	—
·119	·007	—	—	1188	25	·0222	—	1094	—	—	—	—	—	—
·178	·0105	—	—	—	—	—	—	—	·524 [4]	26·0	—	—	—	—
·255	·015	—	—	1153	25	—	—	1061	—	—	—	—	—	—
·42	·025	—	—	1126	25	·0217	—	1037	·522 ·538	26·0 0·0	—	—	—	—
·842	·05	1·007	18·0	1086	25	—	—	1000	—	—	—	—	—	—
—	·052	—	—	—	—	—	—	—	·524	26·0	—	—	—	—
1·657	·1	1·0131	18·0	1022	25	·0213	—	941	—	—	—	—	—	—
—	·104	—	—	—	—	—	—	—	·528	20·0	—	—	—	—
·00763	·00045	—	—	—	18	·0228	1040 [5]	1105	—	—	—	—	—	—
·00915	·00054	—	—	—	18	·0229	1030	1095	—	—	—	—	—	—
·0166	·00097	—	—	—	18	·0227	1010	1074	—	—	—	—	—	—
·0410	·00242	—	—	—	18	—	990	1052	—	—	—	—	—	—

Zeitschrift für Physik. Chemie, vol. ii. p. 956.

[5] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

STRONTIUM NITRATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Sr(NO_3)_2$, 105·54.

5·0	·494	1·0418	15	289 [1]	18	·0225	585	622	—	—	·125	1080 [3]	25	—
10·0	1·029	1·0857	15	493	18	·0225	479	509	—	—	·25	1067	25	—
15·0	1·608	1·1318	15	645	18	·0227	401	426	—	—	·5	1042	25	—
20·0	2·240	1·1815	15	750	18	·0228	335	356	—	—	1·0	980	25	—
25·0	2·929	1·2363	15	810	18	·0226	277	294	—	—	—	—	—	—
35·0	4·490	1·3542	15	805	18	·0241	179	190	—	—	—	—	—	—
·00918	·00087	—	—	—	18	—	980 [2]	1042	—	—	·125	961 [4]	20	—
·01076	·00102	—	—	—	18	—	990	1052	—	—	·25	931	20	—
·01604	·00152	—	—	—	18	—	950	1010	—	—	·5	878	20	—
·03747	·00355	—	—	—	18	—	920	978	—	—	1·0	777	20	—

[1] Long, *Wied. Annal.* vol. xi. p. 37.

[2] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.

[4] Mutzel, *Wied. Annal.* vol. xliii. p. 21.

BARIUM NITRATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Ba(NO_3)_2$, 130·54.

			°		°					°			°	
·00013	·00001	—	—	—	18	—	1114 [1]	1185	—	—	—	—	—	—
·000261	·00002	—	—	—	18	—	1114	1185	—	—	—	—	—	—
·000783	·00006	—	—	—	18	—	1100	1170	—	—	—	—	—	—
·0013	·0001	—	—	—	18	—	1096	1165	—	—	·125	1084 [4]	25	—
·00261	·0002	—	—	—	18	—	1084	1152	—	—	·25	1070	25	—
·00783	·0006	—	—	—	18	—	1066	1133	—	—	·5	1047	25	—
·013	·001	—	—	—	18	—	1054	1121	—	—	—	—	—	—
·0261	·002	—	—	—	18	—	1033	1098	—	—	—	—	—	—
·0783	·006	—	—	—	18	—	982	1044	—	—	·125	962 [5]	20	—
·1305	·01	—	—	—	18	·0224	951	1011	—	—	·25	938	20	—
·391	·03	—	—	—	18	—	870	925	—	—	—	—	—	—
·648	·05	1·0052	19·5	—	18	—	828	880	—	—	—	—	—	—
·743	·057	1·0060	10·6	—	—	—	—	—	·602 [3]	—	—	—	—	—
1·29	·1	1·0113	19·5	—	18	—	755	802	—	—	—	—	—	—
1·74	·135	1·0146	13·6	—	—	—	—	—	·620	—	—	—	—	—
5·8	·466	1·0502	8·0	—	—	—	—	—	·641	—	—	—	—	—
6·20	·5	1·0520	19·5	—	18	·0241	531	564	—	—	—	—	—	—
·00665	·00051	—	—	—	18	—	1010 [2]	1073	—	—	—	—	—	—
·0137	·00105	—	—	—	18	—	1000	1063	—	—	—	—	—	—
·0249	·00191	—	—	—	18	—	980	1042	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 381.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 35.

[5] Mutzel, *Wied. Annal.* vol. xliii. p. 25.

CALCIUM NITRATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Ca(NO_3)_2$, 82·04.

3·98	·5	1·0307	18·0	314·0 [1]	18	·0219	628	668	—	—	—	—	—	—
7·73	1·0	1·0608	18·0	541·0	18	·0219	541	575	—	—	—	—	—	—
14·64	2·0	1·1202	18·0	818·0	18	·0217	409	435	—	—	—	—	—	—
20·9	3·0	1·1781	18·0	946·0	18	·0217	315	335	—	—	·125	1092 [2]	25	—
26·57	4·0	1·2352	18·0	983·0	18	·0220	246	261	—	—	·25	1069	25	—
—	5·0	—	—	946·0	18	·0230	189	201	—	—	·5	1038	25	—
—	6·0	—	—	845·0	18	·0250	141	150	—	—	1·0	978	25	—
—	7·0	—	—	716·0	18	·0275	102	108	—	—	—	—	—	—
—	8 0	—	—	584·0	18	·0302	73	78	—	—	—	—	—	—
—	9·0	1·4984	18·0	461·0	18	·0331	51	54	—	—	—	—	—	—
—	10·0	—	—	355·0	18	·0363	35	37	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.

[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.

·0255	·00312	—	—	30·34 [3]	18	—	971	1032	—	—	·125	961 [5]	20	—
·051	·00625	—	—	57·87	18	—	925	988	—	—	·25	927	20	—
·102	·0125	—	—	112·2	18	—	898	955	—	—	·5	867	20	—
·203	·025	—	—	209·6	18	—	838	891	—	—	1·0	766	20	—
·407	·05	—	—	395·5	18	—	791	841	—	—	—	—	—	—
·814	·1	1·0069	18·0	730·0	18	—	730	776	—	—	—	—	—	—
·9	·11	1·0070	7·4	—	—	—	—	—	·613 [4]	—	—	—	—	—
1·62	·2	1·0135	18·0	1324·0	18	—	662	704	—	—	—	—	—	—
20·16	2·88	1·1707	7·4	—	—	—	—	—	·652	—	—	—	—	—
41·32	7·15	1·3919	7·6	—	—	—	—	—	·718	—	—	—	—	—

[3] Fitzpatrick, *Phil. Mag.* (5th series), vol. xxvi. p. 377.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 381.

[5] Mutzel, *Wied. Annal.* vol. xliii. p. 26.

Magnesium Nitrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Mg(NO_3)_2$, 74·04.

3·612	·5	1·0249	21	309·0 [1]	18	·0218	618	657	—	—	—	—	—	—
7·052	1·0	1·0499	21	546·0	18	·0215	546	580	—	—	—	—	—	—
13·47	2·0	1·0994	21	890·0	18	·0211	445	473	—	—	·125	1072 [3]	25	—
19·34	3·0	1·1482	21	1096·0	18	·0207	365	388	—	—	·25	1051	25	—
									—	—	·5	1010	25	—
·0116	·00156	—	—	12·68 [2]	18	—	811	862	—	—	1·0	934	25	—
·0232	·00312	—	—	25·0	18	—	800	850	—	—	—	—	—	—
·0465	·00625	—	—	48·7	18	—	779	828	—	—	·125	944 [4]	20	—
093	·0125	—	—	93·4	18	—	747	794	—	—	·25	907	20	—
·185	·025	—	—	182·4	18	—	730	776	—	—	·5	840	20	—
·37	·05	—	—	343·5	18	—	687	730	—	—	1·0	720	20	—
·737	·1	1·0051	21	643·6	18	—	644	685	—	—	—	—	—	—
1·465	·2	1·0099	21	1200·0	18	—	600	638	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.

[2] Fitzpatrick, *Phil. Mag.* (5th series), vol. xxiv. p. 377.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 37.

[4] Mutzel, *Wied. Annal*, vol. xliii. p. 26.

Cadmium Nitrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Cd(NO_3)_2$, 117·9.

·0492	·00418	·9990	18	3·95 [1]	18	·0234	935	994	—	—	—	—	—	—
·1	·00849	·9994	18	7·59	18	·0233	894	950	—	—	·125	1074 [3]	25	—
·249	·02123	1·0007	18	18·1	18	·0227	853	907	—	—	·25	1052	25	—
·464	·03951	1·0025	18	32·5	18	·0230	823	875	—	—	·5	1017	25	—
·952	·08146	1·0065	18	62·7	18	·0222	769	817	—	—	1·0	938	25	—
1·014	·0868	1·0070	18	65·2 [2]	18	·0226	751	798	—	—	—	—	—	—
5·02	·444	1·0416	18	270·0	18	·0221	608	646	—	—	—	—	—	—
10·07	·930	1·0875	18	480·0	18	·0215	516	548	—	—	—	—	—	—

[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 493.

[2] Grotian, *Wied. Annal.* vol. xviii. p. 194.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.

Cadmium Nitrate—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Cd(NO_3)_2$, 117·9.

			°		°					°			°		
20·2	2·047	1·1926	18	773·0	18	·0212	377	401	—	—	—	—	—	—	
30·0	3·345	1·3124	18	891·0	18	·0214	266	283	—	—	—	—	—	—	
40·0	4·957	1·4589	18	841·0	18	·0228	169	179	—	—	—	—	—	—	
48·3	6·580	1·6034	18	697·0	18	·0253	106	113	—	—	—	—	—	—	

Lead Nitrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Pb(NO_3)_2$, 165·1.

·0081	·00049	—	—	—	—	·0231	1100 [1]	1169	—	—	—	—	—	—	[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.
·0125	·00076	—	—	—	—	—	1060	1127	—	—	—	—	—	—	
·0248	·0015	—	—	—	—	—	1010	1074	—	—	—	—	—	—	
5·0	·317	1·0449	15	179 [2]	18	·0238	565	601	—	—	·125	1086 [3]	25	—	[2] Long, *Wied. Annal.* vol. xi. p. 37.
10·0	·663	1·0937	15	301	18	·0251	454	483	—	—	·25	1074	25	—	
15·0	1·042	1·1467	15	401	18	·0251	385	409	—	—	·5	1049	25	—	
20·0	1·460	1·2043	15	487	18	·0250	334	355	—	—	1·0	993	25	—	[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.
25·0	1·920	1·2678	15	561	18	·0252	292	310	—	—	—	—	—	—	
30·0	2·427	1·3358	15	625	18	·0257	216	230	—	—	—	—	—	—	

Chloric Acid.

Equivalent Gramme Molecule, $HClO_3$, 84·25.

·0082	·000976	—	—	384·8 [1]	25	—	—	4090 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 75.
·0165	·00195	—	—	381·5	25	—	—	4055	—	—	—	—	—	—	
·033	·0039	—	—	377·0	25	—	—	4087	—	—	—	—	—	—	
·066	·0078	—	—	371·0	25	—	—	3944	—	—	—	—	—	—	
·132	·0156	—	—	363·8	25	—	—	3867	—	—	—	—	—	—	[2] At 25°.
·262	·0312	—	—	355·4	25	—	—	3778	—	—	—	—	—	—	

Potassium Chlorate.

Equivalent Gramme Molecule, $KClO_3$, 122·59.

·000122	·00001	—	—	—	18	—	1141 [1]	1213	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.
·000245	·00002	—	—	—	18	—	1135	1206	—	—	—	—	—	—	
·000735	·00006	—	—	—	18	—	1126	1197	—	—	—	—	—	—	
·00122	·0001	—	—	—	18	—	1122	1193	—	—	—	—	—	—	
·00245	·0002	—	—	—	18	—	1119	1190	—	—	—	—	—	—	

00735	·0006	—	—	—	18	—	1109	1179	—	—	—	—	—	—
1226	·001	—	—	—	18	—	1101	1171	—	—	—	—	—	—
·0245	·002	—	—	—	18	—	1091	1160	—	—	—	—	—	—
·0735	·006	—	—	—	18	—	1068	1135	—	—	—	—	—	—
·1226	·01	—	—	—	18	·0219	1053	1120	—	—	—	—	—	—
·367	·03	—	—	—	18	—	1006	1069	—	—	—	—	—	—
·609	·05	—	—	—	18	—	976	1037	—	—	—	—	—	—
·86	—	—	—	—	—	—	—	—	·462 [2]	—	—	—	—	—
1·215	·1	1·0085	19·5	—	18	—	927	985	—	—	—	—	—	—
3·62	—	—	—	—	—	—	—	—	·445	—	—	—	—	—
5·903	·5	1·0384	19·5	—	18	·0212	799	849	—	—	—	—	—	—
·012	·000976	—	—	130·2 [3]	25	—	—	1200	—	—	—	—	—	—
·024	·00195	—	—	126·8	25	—	—	1169	—	—	—	—	—	—
·048	·0039	—	—	123·3	25	—	—	1136	—	—	—	—	—	—
·096	·0078	—	—	120·0	25	—	—	1106	—	—	—	—	—	—
·191	·0156	—	—	116·6	25	—	—	1075	—	—	—	—	—	—
·382	·0312	—	—	112·5	25	—	—	1037	—	—	—	—	—	—

[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 375.

[3] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 85.

Sodium Chlorate.

Equivalent Gramme Molecule, $NaClO_3$, 106·5.

—	—	—	—	—	—	—	—	—	—	—	1·168 [3]	891	20	—
·0104	·000976	—	—	106·6 [1]	25	—	—	1133 [2]	—	—	2·23	785	20	—
·0208	·00195	—	—	104·1	25	—	—	1106	—	—	3·992	586	20	—
·0415	·0039	—	—	101·5	25	—	—	1079	—	—	—	—	—	—
·0825	·0078	—	—	98·6	25	—	—	1048	—	—	—	—	—	—
·165	·0156	—	—	95·8	25	—	—	1018	—	—	—	—	—	—
·331	·0312	—	—	92·7	25	—	—	985	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 81.

[2] At 25°.

[3] Sprung, *Pogg. Annal.* vol. cvi. p. 15.

Lithium Chlorate.

Equivalent Gramme Molecule, $LiClO_3$, 90·48.

·00877	·000976	—	—	97·0 [1]	25	—	—	1031 [2]	—	—	—	—	—	—
·01755	·00195	—	—	94·2	25	—	—	1001	—	—	—	—	—	—
·0351	·0039	—	—	91·9	25	—	—	977	—	—	—	—	—	—
·0702	·0078	—	—	89·1	25	—	—	947	—	—	—	—	—	—
·1405	·0156	—	—	86·4	25	—	—	918	—	—	—	—	—	—
·281	·0312	—	—	83·7	25	—	—	890	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 83.

[2] At 25°.

Perchloric Acid.

Equivalent Gramme Molecule, $HClO_4$, 100·46.

			°		°					°			°		
·00976	·000976	—	—	395·5 [1]	25	—	—	4204 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 76.
·00195	·00195	—	—	391·0	25	—	—	4156	—	—	—	—	—	—	
·039	·0039	—	—	384·8	25	—	—	4090	—	—	—	—	—	—	
·078	·0078	—	—	378·0	25	—	—	4018	—	—	—	—	—	—	[2] At 25°.
·156	·0156	—	—	369·5	25	—	—	3928	—	—	—	—	—	—	
·313	·0312	—	—	361·2	25	—	—	3840	—	—	—	—	—	—	

Potassium Perchlorate.

Equivalent Gramme Molecule, $KClO_4$, 138·59.

·0135	·000976	—	—	139·8 [1]	25	—	—	1486 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 85.
·027	·00195	—	—	136·4	25	—	—	1450	—	—	—	—	—	—	
·054	·0039	—	—	132·8	25	—	—	1412	—	—	—	—	—	—	[2] At 25°.
·108	·0078	—	—	129·2	25	—	—	1373	—	—	—	—	—	—	[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 373.
·216	·0156	—	—	124·8	25	—	—	1327	—	—	—	—	—	—	
·431	·0312	—	—	120·7	25	—	—	1283	—	—	—	—	—	—	
·833	—	—	—	—	—	—	—	—	·463 [3]	—	—	—	—	—	

Sodium Perchlorate.

Equivalent Gramme Molecule, $NaClO_4$, 122·5.

·0119	·000976	—	—	116·1 [1]	25	—	—	1234 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 85.
·0238	·00195	—	—	113·3	25	—	—	1204	—	—	—	—	—	—	
·0475	·0039	—	—	110·8	25	—	—	1178	—	—	—	—	—	—	
·095	·0078	—	—	108·2	25	—	—	1150	—	—	—	—	—	—	
·19	·0156	—	—	105·2	25	—	—	1118	—	—	—	—	—	—	[2] At 25°.
·38	·0312	—	—	102·0	25	—	—	1084	—	—	—	—	—	—	

Lithium Perchlorate.

Equivalent Gramme Molecule, $LiClO_4$, 106·48.

·0104	·000976	—	—	107·4 [1]	25	—	—	1142	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 85.
·0208	·00195	—	—	104·4	25	—	—	1119 [2]	—	—	—	—	—	—	
·0415	·0039	—	—	101·6	25	—	—	1080	—	—	—	—	—	—	
·083	·0078	—	—	98·9	25	—	—	1051	—	—	—	—	—	—	
·166	·0156	—	—	95·9	25	—	—	1019	—	—	—	—	—	—	[2] At 25°.
[illegible]	[illegible]	—	—	92·9	25	—	—	987	—	—	—	—	—	—	

SULPHURIC ACID.

Equivalent Gramme Molecule, $\frac{1}{2} H_2SO_4$, 49·035.

·000049	·00001	—	—	—	18	—	1413[1]	1502	—	—	—	—	—	—
·000098	·00002	—	—	—	18	—	2077	2208	—	—	—	—	—	—
·000294	·00006	—	—	—	18	—	2927	3111	—	—	—	—	—	—
·00049	·0001	—	—	—	18	—	3118	3314	—	—	—	—	—	—
·00098	·0002	—	—	—	18	—	3280	3486	—	—	·125[4]	927	18	—
·00294	·0006	—	—	—	18	—	3342	3552	—	—	·25	914	18	—
·0049	·001	—	—	—	18	—	3316	3524	—	—	·5	895	18	—
·0098	·002	—	—	—	18	·0159	3240	3444	—	—	1·0	857	18	—
·0294	·006	—	—	—	18	—	3001	3190	—	—	—	—	—	—
·049	·01	—	—	—	18	·0125	2855	3035	—	—	—	—	—	—
·147	·03	—	—	—	18	—	2515	2673	—	—	—	—	—	—
·245	·05	—	—	—	18	—	2343	2490	—	—	2·176[5]	756	18	·0249
·489	·1	1·0027	15	—	18	—	2084	2215	—	—	4·522	603	18	·0237
·616	—	—	—	—	—	—	—	—	·206[3]	—	7·438	457	18	·0258
·01	—	—	—	—	—	—	—	—	·212	—	10·61	344	18	·0249
2·414	·5	1·0155	15	—	18	—	1899	2018	—	—	14·33	242	18	·0242
4·1	—	—	—	—	—	—	—	—	·177	—	18·25	160	18	·0259
4·758	1·0	1·0304	15	—	18	—	1820	1935	—	—	23·17	86	18	·0302
13·44	3·0	1·0941	15	—	18	—	1560	1658	—	—	29·28	37	18	·0423
15·59	—	—	—	—	—	—	—	—	·174	—	30·8	34	18	·0432
21·25	5·0	1·1534	15	—	18	—	1270	1350	—	—	32·18	34	18	·0421
38·03	10·0	1·2894	15	—	18	—	660	701	—	—	—	—	—	—
41·0	—	—	—	—	—	—	—	—	·288	—	—	—	—	—
64·22	—	—	—	—	—	—	—	—	·4	—	—	—	—	—
·098	·02	—	—	51·9[2]	18	—	2595	2758	—	—	—	—	—	—
·196	·04	—	—	95·3	18	—	2382	2532	—	—	—	—	—	—
·391	·08	1·0020	15	175·6	18	—	2195	2333	—	—	—	—	—	—
·78	·16	1·0048	15	326·9	18	—	2043	2171	—	—	—	—	—	—
1·553	·32	1·0100	15	613·8	18	—	1918	2038	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Hittorf, *Pogg. Annal.* vol. cvi. p. 401.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.

[5] Grotian, *Wied. Annal.* vol. viii. p. 543.

POTASSIUM SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2} K_2SO_4$, 87·16.

·000087	·00001	—	—	—	18	—	1275[1]	1355	—	—	—	—	—	—
·000174	·00002	—	—	—	18	—	1266	1346	—	—	—	—	—	—
·000523	·00006	—	—	—	18	—	1254	1333	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

POTASSIUM SULPHATE—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ K_2SO_4, 87·16.

			°		°					°			°	
·00087	·0001	—	—	—	18	—	1249	1328	—	—	·618	916 [5]	20	·0244
·00174	·0002	—	—	—	18	—	1241	1319	—	—	1·209	861	20	·0235
·00523	·0006	—	—	—	18	—	1220	1297	—	—	—	—	—	—
·0087	·001	—	—	—	18	—	1207	1283	—	—	—	—	—	—
·0174	·002	—	—	—	18	—	1181	1256	—	—	1·0	888 [6]	20	—
·0523	·006	—	—	—	18	—	1130	1201	—	—	—	—	—	—
·0871	·01	—	—	—	18	·0223	1098	1167	—	—	·125	966 [7]	20	—
·241	·028	1·0020	6·6	—	—	—	—	—	·498 [4]	—	·25	954	20	—
·261	·03	1·0015	15·0	—	18	—	1008	1071	—	—	·5	928	20	—
·434	·05	1·0030	15·0	—	18	—	959	1019	—	—	1·0	883	20	—
·866	·1	1·0069	15·0	—	18	—	897	954	—	—	—	—	—	—
4·212	·5	1·0345	15·0	—	18	·0218	736	782	—	—	—	—	—	—
7·67	·936	1·0639	12·0	—	—	—	—	—	·499	—	—	—	—	—
8·163	1·0	1·0677	15·0	—	18	·0209	672	714	—	—	—	—	—	—
·542	·0625	1·0040	15·0	57·0 [2]	18	—	912	969	—	—	—	—	—	—
·629	·0725	1·0047	15·0	65·5	18	—	903	960	—	—	—	—	—	—
1·080	·125	1·0088	15·0	106·0	18	—	848	899	—	—	—	—	—	—
1·251	·145	1·0102	15·0	121·0	18	—	834	889	—	—	—	—	—	—
2·477	·29	1·0202	15·0	223·0	18	—	769	817	—	—	—	—	—	—
4·212	·5	1·0345	15·0	361·0	18	—	722	767	—	—	—	—	—	—
·00558	·00064	—	—	—	18	·0238	1250 [3]	1329	—	—	—	—	—	—
·0074	·00085	—	—	—	18	·0237	1210	1286	—	—	—	—	—	—
·0135	·00155	—	—	—	18	·0239	1160	1233	—	—	—	—	—	—
·0286	·00325	—	—	—	18	·0231	1090	1159	—	—	—	—	—	—
·0862	·0099	—	—	—	18	·0223	1020	1084	—	—	—	—	—	—

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

[4] Hittorf, *Pogg. Annal.* vol. xcviii. p. 27.

[5] Sprung, *Pogg. Annal.* vol. clix. p. 16.

[6] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[7] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 37.

AMMONIUM SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $(NH_4)_2SO_4$, 66·075.

3·236	·5	1·0186	15	351 [1]	18	·0221	702	746	—	—	—	—	—	—
6·360	1·0	1·0366	15	643	18	·0212	643	683	—	—	—	—	—	—
12·312	2·0	1·0708	15	1130	18	·0201	565	601	—	—	1·282	853 [3]	20	·0238
17·926	3·0	1·1032	15	1535	18	·0195	512	544	—	—	2·637	745	20	·0229
[illegible]	4·0	—	—	1856	18	·0193	464	493	—	—	4·438	600	20	·0231

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 150.

28·336	5·0	1·1632	15	2087	18	·0192	417	443	—	—	—	—	—	—
—	6·0	—	—	2233	18	·0193	372	395	—	—	—	—	—	—
·411	·0625	1·0018	15	56 [2]	18	—	896	952	—	—	—	—	—	—
·820	·125	1·0045	15	103	18	—	824	876	—	—	—	—	—	—
1·632	·25	1·0095	15	190	18	—	760	808	—	—	—	—	—	—
3·236	·5	1·0186	15	347	18	—	694	738	—	—	—	—	—	—

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Sprung, *Pogg. Annal.* vol. clix. p. 16.

Sodium Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ Na_2SO_4, 71·075.

·000071	·00001	—	—	—	18	—	1054 [1]	1121	—	—	—	—	—	—
·000142	·00002	—	—	—	18	—	1056	1123	—	—	—	—	—	—
·000426	·00006	—	—	—	18	—	1038	1103	—	—	—	—	—	—
·00071	·0001	—	—	—	18	—	1034	1099	—	—	·485	880 [5]	20	·0255
·00142	·0002	—	—	—	18	—	1026	1091	—	—	·989	795	20	·0247
·00426	·0006	—	—	—	18	—	1009	1072	—	—	1·996	630	20	·0257
·0071	·001	—	—	—	18	—	998	1060	—	—	—	—	—	—
·0142	·002	—	—	—	18	—	980	1042	—	—	1·0	796 [6]	20	—
·0426	·006	—	—	—	18	—	933	992	—	—	—	—	—	—
·071	·01	—	—	—	18	·0240	906	963	—	—	·125	948 [7]	20	—
·213	·03	—	—	—	18	·0240	828	880	—	—	·25	922	20	—
·355	·05	—	—	—	18	—	784	833	—	—	·5	877	20	—
·706	·1	1·0062	15	—	18	—	734	780	—	—	1·0	789	20	—
1·93	·276	1·0181	9	—	—	—	—	—	·634 [4]	—	—	—	—	—
3·542	·5	1·0317	15	—	18	·0232	559	594	—	—	—	—	—	—
6·70	1·0	1·0612	15	—	18	·0242	475	505	—	—	—	—	—	—
7·83	1·18	1·0735	9	—	—	—	—	—	·641	—	—	—	—	—
12·70	2·0	1·1190	15	—	18	·0254	376	400	—	—	—	—	—	—
·444	·0625	—	—	46·7 [2]	18	—	747	794	—	—	—	—	—	—
·881	·125	1·0080	15	85·5	18	—	684	727	—	—	—	—	—	—
1·750	·25	1·0158	15	154·0	18	—	616	654	—	—	—	—	—	—
3·542	·5	1·0317	15	272·0	18	—	544	578	—	—	—	—	—	—
·00604	·00085	—	—	—	18	—	1010 [3]	1074	—	—	—	—	—	—
·00974	·00137	—	—	—	18	—	970	1031	—	—	—	—	—	—
·01834	·00258	—	—	—	18	—	940	999	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 377.

[5] Sprung, *Pogg. Annal.* vol. clix. p. 15.

[6] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[7] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 39.

Lithium Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ Li_2SO_4, 55·05.

			°		°					°			°	
·000055	·00001	—	—	—	18	—	949 [1]	1008	—	—	—	—	—	—
·00011	·00002	—	—	—	18	—	950	1009	—	—	—	—	—	—
·00033	·00006	—	—	—	18	—	950	1009	—	—	—	—	—	—
·00055	·0001	—	—	—	18	—	945	1004	—	—	—	—	—	—
·0011	·0002	—	—	—	18	—	937	996	—	—	1·0	712 [3]	17·6	—
·0033	·0006	—	—	—	18	—	918	976	—	—	—	—	—	—
·0055	·001	—	—	—	18	—	906	963	—	—	—	—	—	—
·011	·002	—	—	—	18	—	885	941	—	—	·125	1059 [4]	25·0	—
·033	·006	—	—	—	18	—	844	897	—	—	·25	1026	25·0	—
·055	·01	—	—	—	18	·0242	818	870	—	—	·5	961	25·0	—
·165	·03	—	—	—	18	—	742	789	—	—	1·0	847	25·0	—
·275	·05	—	—	—	18	—	701	745	—	—	—	—	—	—
—	·09	—	—	—	—	—	—	—	·595 [2]	—	—	—	—	—
·548	·1	—	—	—	18	—	637	677	—	—	—	—	—	—
—	·159	—	—	—	—	—	—	—	·649	—	—	—	—	—
2·7	·5	—	—	—	18	·0236	474	504	—	—	—	—	—	—
5·27	1·0	1·0445	18·6	—	18	·0237	386	410	—	—	—	—	—	—
—	2·0	—	—	—	18	·0240	287	305	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Kuschel, *Wied. Annal.* vol. xiii. p. 300.

[3] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 38.

Silver Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ Ag_2SO_4, 155·9.

·0071	·00046	—	—	—	18	—	1090 [1]	1159	—	—	—	—	—	—
·0124	·00080	—	—	—	18	—	1050	1116	—	—	—	—	—	—
·0263	·00169	—	—	—	18	—	1010	1073	—	—	—	—	—	—
·0473	·00344	—	—	—	18	—	970	1031	—	—	—	—	—	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

Magnesium Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $MgSO_4$, 60·035.

·00006	·00001	—	—	—	18	—	1056 [1]	1123	—	—	—	—	—	—
·00012	·00002	—	—	—	18	—	1052	1119	—	—	—	—	—	—
·00036	·00006	—	—	—	18	—	1036	1101	—	—	—	—	—	—
·0006	·0001	—	—	—	18	—	1034	1099	—	—	—	—	—	—
·0012	·0002	—	—	—	18	—	1015	1079	—	—	·8715	746 [2]	20	·0258
·0036	·0006	—	—	—	18	—	967	1028	—	—	1·738	554	20	·0283

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Sprung, *Pogg. Annal.* vol. clix. p. 19.

·006	·001	—	—	—	18	—	935	994	—	—	2·69	393	20	·0306
·012	·002	—	—	—	18	—	881	937	—	—	3 9	249	20	·0332
·036	·006	—	—	—	18	—	773	822	—	—	—	—	—	—
·06	·01	—	—	—	18	·0236	715	760	—	—	1·0	711[5]	20	—
·18	·03	—	—	—	18	—	587	624	—	—	—	—	—	—
·299	·05	1·0025	15·0	—	18	—	532	565	—	—	·125	937[6]	20	—
·475	·0795	1·0048	4·8	—	—	—	—	—	·656[4]	—	·25	896	20	—
·597	·1	1·0058	15·0	—	18	—	474	504	—	—	·5	831	20	—
2·912	·5	1·0300	15·0	—	18	·0222	330	351	—	—	1·0	701	20	—
5·67	1·0	1·0587	15·0	—	18	·0229	270	287	—	—	—	—	—	—
15·43	3·0	1·1673	15·0	—	18	·0254	151	160	—	—	—	—	—	—
15·92	3·12	1·1763	3·6	—	—	—	—	—	·762	—	—	—	—	—
·00575	·000976	—	—	1133[8]	25	—	—	1023	—	—	—	—	—	—
·0117	·00195	—	—	1055	25	—	—	952	—	—	—	—	—	—
·0234	·0039	—	—	966	25	—	—	876	—	—	—	—	—	—
·0468	·0078	—	—	869	25	—	—	790	—	—	—	—	—	—
·0935	·0156	—	—	772	25	—	—	703	—	—	—	—	—	—
·187	·0312	—	—	678	25	—	—	618	—	—	—	—	—	—

[3] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 109.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 382.

[5] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[6] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 38.

ZINC SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $ZnSO_4$, 80·58.

·00008	·00001	—	—	—	18	—	1060[1]	1127	—	—	—	—	—	—
·000161	·00002	—	—	—	18	—	1047	1113	—	—	—	—	—	—
·000483	·00006	—	—	—	18	—	1032	1097	—	—	—	—	—	—
·0008	·0001	—	—	—	18	—	1023	1088	—	—	·0625	946[3]	20	—
·00161	·0002	—	—	—	18	—	1001	1064	—	—	·125	925	20	—
·00483	·0006	—	—	—	18	—	953	1013	—	—	·25	886	20	—
·008	·001	—	—	—	18	—	919	977	—	—	·5	817	20	—
·0161	·002	—	—	—	18	—	861	915	—	—	1·0	701	20	—
·0483	·006	—	—	—	18	—	744	791	—	—	—	—	—	—
·08	·01	—	—	—	18	·0234	685	728	—	—	1·0	723[4]	20	—
·242	·03	—	—	—	18	—	556	591	—	—	—	—	—	—
·373	—	—	—	—	—	—	—	—	·636[2]	—	·986	708[5]	20	·028
·4	·05	1·0041	15	—	18	—	500	530	—	—	1·537	595	20	·0297
·799	·1	1·0090	15	—	18	—	431	458	—	—	2·144	478	20	·0313
3·85	·5	1·0404	15	—	18	·0226	302	321	—	—	2·993	349	20	·0341

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 385.

[3] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 40.

[4] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[5] Grotian, *Pogg. Annal.* vol. clx. p. 263.

ZINC SULPHATE—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ $ZnSO_4$, 80·58.

			°		°					°			°	
7·456	1·0	1·0807	15	—	18	·0224	249	265	—	—	3·555	284	20	·0338
19·637	3·0	1·2310	15	—	18	·0241	146	155	—	—	5·085	161	20	·0384
19·8	—	—	—	—	—	—	—	—	·760	—	—	—	—	—
28·38	—	—	—	—	—	—	—	—	·778	—	—	—	—	—
29·36	5·0	1·372	15	—	18	·0277	82	87	—	—	—	—	—	—
·008	·001	—	—	1·02 [6]	18	—	—	980	—	—	—	—	—	—
·080	·01	—	—	7·38	18	—	—	734	—	—	—	—	—	—
·799	·1	1·0090	15	46·46	18	—	—	466	—	—	—	—	—	—
1·583	·2	1·0179	15	77·3	18	—	—	386	—	—	—	—	—	—
3·85	·5	1·0404	15	152·0	18	—	—	304	—	—	—	—	—	—
·00459	·00057	—	—	—	18	—	950 [7]	1010	—	—	—	—	—	—
·00604	·00075	—	—	—	18	—	910	967	—	—	—	—	—	—
·0104	·00129	—	—	—	18	—	850	903	—	—	—	—	—	—
·0270	·00335	—	—	—	18	—	760	808	—	—	—	—	—	—
7·18	·961	1·0780	15	228·0 [8]	18	—	—	252	—	—	—	—	—	—
9·34	1·276	1·1012	15	274·0	18	—	—	228	—	—	—	—	—	—
11·88	1·668	1·1317	15	319·0	18	—	—	203	—	—	—	—	—	—
15·60	2·282	1·1790	15	378·0	18	—	—	176	—	—	—	—	—	—
17·75	2·656	1·2063	15	425·0	18	—	—	170	—	—	—	—	—	—
19·61	2·996	1·2310	15	430·0	18	—	—	153	—	—	—	—	—	—
20·41	3·148	1·2430	15	431·0	18	—	—	146	—	—	—	—	—	—
22·44	3·539	1·2710	15	440·0	18	—	—	132	—	—	—	—	—	—
22·59	3·574	1·2746	15	440·0	18	—	—	131	—	—	—	—	—	—
23·15	3·603	1·2832	15	441·0	18	—	—	130	—	—	—	—	—	—
23·66	3·788	1·2901	15	445·0	18	—	—	125	—	—	—	—	—	—
24·88	3·913	1·2986	15	442·0	18	—	—	120	—	—	—	—	—	—
25·28	4·116	1·3120	15	439·0	18	—	—	113	—	—	—	—	—	—
26·81	4·448	1·3370	15	431·0	18	—	—	103	—	—	—	—	—	—
32·50	5·752	1·4260	15	374·0	18	—	—	69	—	—	—	—	—	—
33·71	—	—	—	359·0	18	—	—	—	—	—	—	—	—	—
35·04	—	—	—	336·0	18	—	—	—	—	—	—	—	—	—
37·81	—	—	—	294·0	18	—	—	—	—	—	—	—	—	—

[6] Bouty, *Journ. de Physique*, vol. vi. p. 13.

[7] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

[8] Beetz, *Pogg. Annal.* vol. cxvii. p. 9.

COPPER SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CuSO_4$, 79·78.

·00008	·00001	—	—	—	18	—	1086 [1]	1154	—	—	—	—	—	—
·00016	·00002	—	—	—	18	—	1084	1152	—	—	—	—	—	—
·00048	·00006	—	—	—	18	—	1074	1142	—	—	—	—	—	—
·0008	·0001	—	—	—	18	—	1062	1129	—	—	—	—	—	—
·0016	·0002	—	—	—	18	—	1039	1104	—	—	1·0	675 [4]	17·6	—
·0048	·0006	—	—	—	18	—	987	1049	—	—	—	—	—	—
·008	·001	—	—	—	18	—	950	1009	—	—	·0625	1073 [5]	25·0	—
·016	·002	—	—	—	18	—	873	928	—	—	·125	1052	25·0	—
·048	·006	—	—	—	18	—	740	787	—	—	·25	1012	25·0	—
·08	·01	—	—	—	18	·0229	675	717	—	—	·5	942	25·0	—
·239	·03	1·0015	18·0	—	18	—	537	571	—	—	1·0	805	25·0	—
·397	·05	1·0034	18·0	—	18	—	479	509	—	—	—	—	—	—
·671	·0846	1·0071	4·4	—	—	—	—	—	·638 [3]	4·4	—	—	—	—
·791	·1	1·0078	18·0	—	18	—	424	451	—	—	—	—	—	—
1·282	·163	1·0135	4·8	—	—	—	—	—	·651	4·3	—	—	—	—
2·457	·315	1·0254	3·0	—	—	—	—	—	·644	4·5	—	—	—	—
3·847	·5	1·0386	18·0	—	18	·0216	288	306	—	—	—	—	—	—
5·235	·692	1·0553	3·6	—	—	—	—	—	·675	5·5	—	—	—	—
7·418	1·0	1·0758	18·0	—	18	·0218	241	256	—	—	—	—	—	—
9·47	1·31	1·1036	4·9	—	—	—	—	—	·712	6·5	—	—	—	—
13·6	1·962	1·1521	4·5	—	—	—	—	—	·724	5·5	—	—	—	—
—	3·0	—	—	—	18	·0241	150	159	—	—	—	—	—	—
·00486	·00061	—	—	—	18	—	1020 [2]	1084	—	—	—	—	—	—
·00622	·00078	—	—	—	18	—	970	1031	—	—	—	—	—	—
·00989	·00124	—	—	—	18	—	950	1010	—	—	—	—	—	—
·0156	·00196	—	—	—	18	—	840	893	—	—	—	—	—	—
·0251	·00315	—	—	—	18	—	800	850	—	—	—	—	—	—
·0411	·0064	—	—	—	18	—	700	744	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

[3] Hittorf, *Pogg. Annal.* vol. xcviii. p. 196.

[4] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[5] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 38.

CADMIUM SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CdSO_4$, 104·03.

·0289	·00278	·99893	18	2·3 [1]	18	·0230	827	879	—	—	—	—	—	—
·0489	·00482	·99915	18	3·62	18	·0230	750	797	—	—	—	—	—	—

[1] Wershoven, *Zeitschrift für Physik. Chemie*, vol. v. p. 494.

Cadmium Sulphate—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CdSO_4$, 104·03.

			°		°					°			°	
·0999	·00961	·99961	18	6·43	18	·0222	668	710	—	—	·125	1057 [4]	25	—
—	—	—	—	—	—	—	—	—	—	—	·25	1014	25	—
·495	·0479	1·0034	18	22·24	18	·0211	459	499	—	—	·5	944	25	—
·981	·0954	1·0084	18	37·82	18	·0207	396	421	—	—	1·0	811	25	—
·282	·0272	1·0015	18	14·3 [2]	18	·0221	525	558	—	—	—	—	—	—
1·011	·0983	1·0085	18	38·9	18	·0210	396	421	—	—	—	—	—	—
5·08	·514	1·0495	18	137·0	18	·0206	266	283	—	—	—	—	—	—
10·11	1·076	1·1039	18	232·0	18	·0206	216	230	—	—	—	—	—	—
25·03	3·127	1·2955	18	400·0	18	·0223	128	136	—	—	—	—	—	—
36·07	5·133	1·4756	18	392·0	18	·0255	76	81	—	—	—	—	—	—
·00655	·00063	—	—	—	18	—	930 [3]	989	—	—	—	—	—	—
·00936	·0009	—	—	—	18	—	890	946	—	—	—	—	—	—
·01633	·00157	—	—	—	18	—	820	871	—	—	—	—	—	—

[2] Grotian, *Wied. Annal.* vol. xviii. p. 193.

[3] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 689.

[4] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 36.

Ferrous Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $FeSO_4$, 76·03.

·00684	·0009	—	—	—	18	·0296	780 [1]	829	—	—	—	—	—	—
·00973	·00128	—	—	—	18	·0230	760	808	—	—	—	—	—	—
·01193	·00157	—	—	—	18	·0270	730	776	—	—	—	—	—	—
·02417	·00318	—	—	—	18	—	670	712	—	—	—	—	—	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.

Nickel Sulphate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $NiSO_4$, 77·33.

—	—	—	—	—	—	—	—	—	—	—	·125	1059 [2]	25	—
·00572	·00074	—	—	—	18	—	730 [1]	776	—	—	·25	1016	25	—
·00727	·00094	—	—	—	18	—	720	765	—	—	·5	941	25	—
·01392	·0018	—	—	—	18	—	680	723	—	—	1·0	803	25	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.

[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 39.

COBALT SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $CoSO_4$, 77·53.

—	—	—	—	—	—	—	—	—	—	—	·125	1050 [2]	25	—
·00729	·00094	—	—	—	18	—	810 [1]	861	—	—	·25	1015	25	—
·01046	·00135	—	—	—	18	—	780	829	—	—	·5	942	25	—
·02054	·00265	—	—	—	18	—	700	744	—	—	1·0	807	25	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.
[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 39.

ALUMINIUM SULPHATE.

Equivalent Gramme Molecule, $\frac{1}{6}$ $Al_2(SO_4)_3$, 41·02.

·00266	·00065	—	—	—	18	—	810 [1]	861	—	—	·125	1053 [2]	25	—
·00640	·00156	—	—	—	18	—	700	744	—	—	·25	1010	25	—
·00865	·00211	—	—	—	18	—	660	701	—	—	·5	927	25	—
—	—	—	—	—	—	—	—	—	—	—	1·0	777	25	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 690.
[2] Wagner, *Zeitschrift für Physik. Chemie*, vol. v. p. 39.

METHYL SULPHURIC ACID.

Equivalent Gramme Molecule, HCH_3SO_4, 112·07.

·0109	·000976	—	—	368·1 [1]	25	—	—	3913 [2]	—	—	—	—	—	—
·0218	·00195	—	—	365·2	25	—	—	3882	—	—	—	—	—	—
·0435	·0039	—	—	362·8	25	—	—	3857	—	—	—	—	—	—
·087	·0078	—	—	357·8	25	—	—	3803	—	—	—	—	—	—
·174	·0156	—	—	351·4	25	—	—	3735	—	—	—	—	—	—
·349	·0312	—	—	345·0	25	—	—	3667	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 76.
[2] At 25°.

SODIUM METHYL SULPHATE.

Equivalent Gramme Molecule, $NaCH_3SO_4$, 134·1.

·0130	·000976	—	—	91·4 [1]	25	—	—	972 [2]	—	—	—	—	—	—
·0261	·00195	—	—	89·2	25	—	—	948	—	—	—	—	—	—
·0522	·0039	—	—	86·9	25	—	—	924	—	—	—	—	—	—
·1045	·0078	—	—	84·8	25	—	—	901	—	—	—	—	—	—
·209	·0156	—	—	82·2	25	—	—	874	—	—	—	—	—	—
·418	·0312	—	—	79·6	25	—	—	846	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 81.
[2] At 25°.

ETHYL SULPHURIC ACID.

Equivalent Gramme Molecule, $HC_2H_5SO_4$, 126·07.

·0122	·000976	—	° —	367·4 [1]	° 25	—	—	3905 [2]	—	° —	—	—	° —	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 76.
·0245	·00195	—	—	363·9	25	—	—	3868	—	—	—	—	—	—	
·049	·0039	—	—	359·3	25	—	—	3819	—	—	—	—	—	—	
·098	·0078	—	—	353·4	25	—	—	3757	—	—	—	—	—	—	
·196	·0156	—	—	347·6	25	—	—	3695	—	—	—	—	—	—	[2] At 25°.
·392	·0312	—	—	340·9	25	—	—	3624	—	—	—	—	—	—	

SODIUM ETHYL SULPHATE.

Equivalent Gramme Molecule, $NaC_2H_5SO_4$, 148·1.

·0144	·000976	—	—	87·5 [1]	25	—	—	930 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 81.
·0289	·00195	—	—	85·3	25	—	—	907	—	—	—	—	—	—	
·0578	·0039	—	—	83·4	25	—	—	886	—	—	—	—	—	—	
·1155	·0078	—	—	82·1	55	—	—	873	—	—	—	—	—	—	
·231	·0156	—	—	79·8	25	—	—	848	—	—	—	—	—	—	[2] At 25°.
·462	·0312	—	—	77·2	25	—	—	821	—	—	—	—	—	—	

SULPHUROUS ACID.

Equivalent Gramme Molecule, $\frac{1}{2}$ H_2SO_3, 41·03.

·002	·000498	—	—	83·6 [1]	25	—	—	1888 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 314.
·004	·000976	—	—	80·4	25	—	—	1815	—	—	—	—	—	—	
·008	·00195	—	—	77·1	25	—	—	1741	—	—	—	—	—	—	
·016	·0039	—	—	72·5	25	—	—	1637	—	—	—	—	—	—	
·032	·0078	—	—	66·5	25	—	—	1501	—	—	—	—	—	—	[2] At 25°.
·064	·0156	—	—	58·9	25	—	—	1330	—	—	—	—	—	—	
·128	·0312	—	—	50·1	25	—	—	1132	—	—	—	—	—	—	
·256	·0625	—	—	41·6	25	—	—	939	—	—	—	—	—	—	
·512	·125	—	—	32·8	25	—	—	741	—	—	—	—	—	—	
—	·25	—	—	25·4	25	—	—	574	—	—	—	—	—	—	
—	·5	—	—	19·2	25	—	—	434	—	—	—	—	—	—	

SELENIC ACID.

Equivalent Gramme Molecule, $\frac{1}{2}$ H_2SeO_4, 72·4.

·00176	·000244	—	—	173·4 [1]	25	—	—	3915 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 313.
·00352	·000488	—	—	174·4	25	—	—	3937	—	—	—	—	—	—	
·00705	·000976	—	—	173·4	25	—	—	3915	—	—	—	—	—	—	
·0141	·00195	—	—	169·7	25	—	—	3832	—	—	—	—	—	—	[2] At 25°.

·0282	·0039	—	—	164·4	25	—	—	3712	—	—	—	—	—	—	
·0565	·0078	—	—	157 9	25	—	—	3565	—	—	—	—	—	—	
·113	·0156	—	—	148·7	25	—	—	3357	—	—	—	—	—	—	
·226	·0312	—	—	138·3	25	—	—	3122	—	—	—	—	—	—	
·452	·0625	—	—	127·0	25	—	—	2867	—	—	—	—	—	—	
—	·125	—	—	117·7	25	—	—	2658	—	—	—	—	—	—	
—	·25	—	—	109·9	25	—	—	2481	—	—	—	—	—	—	
—	·5	—	—	103·2	25	—	—	2330	—	—	—	—	—	—	
—	1·	—	—	97·3	25	—	—	2197	—	—	—	—	—	—	

SODIUM SELENATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ Na_2SeO_4, 94·44.

·0092	·000976	—	—	115·2 [1]	25	—	—	1225 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 106.
·0184	·00195	—	—	111·6	25	—	—	1186	—	—	—	—	—	—	
·0368	·0039	—	—	107·4	25	—	—	1126	—	—	—	—	—	—	
·0735	·0078	—	—	103·4	25	—	—	1099	—	—	—	—	—	—	
·147	·0156	—	—	98·1	25	—	—	1043	—	—	—	—	—	—	[2] At 25°.
·294	·0312	—	—	92·7	25	—	—	986	—	—	—	—	—	—	

PHOSPHORIC ACID.

Equivalent Gramme Molecule, $\frac{1}{3}$ H_3PO_4, 32·67.

·0012	·000368	—	—	78·8 [1]	25	—	—	1186	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 460.
·0024	·000735	—	—	79·8	25	—	—	1201	—	—	—	—	—	—	
·0048	·00147	—	—	79·0	25	—	—	1189	—	—	—	—	—	—	
·0096	·00295	—	—	75·4	25	—	—	1135	—	—	—	—	—	—	
·0192	·0059	—	—	69·9	25	—	—	1052	—	—	—	—	—	—	[2] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 750.
·0385	·0118	—	—	61·8	25	—	—	931	—	—	—	—	—	—	
·077	·0235	—	—	53·1	25	—	—	799	—	—	—	—	—	—	
·154	·047	—	—	43·0	25	—	—	647	—	—	—	—	—	—	
·307	·094	—	—	34·4	25	—	—	518	—	—	—	—	—	—	
·598	·188	1·0029	15	27·1	25	—	—	408	—	—	·375	1057 [2]	25	—	
1·215	·375	1·0076	15	21·3	25	—	—	321	—	—	·75	1026	25	—	
2·41	·75	1·0136	15	17·0	25	—	—	256	—	—	1·5	964	25	—	
4·76	1·5	1·0263	15	14·2	25	—	—	214	—	—	3·	849	25	—	

POTASSIUM CARBONATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ K_2CO_3, 69·13.

			°		°					°			°	
·000069	·00001	—	—	—	18	—	865[1]	919	—	—	—	—	—	—
·000138	·00002	—	—	—	18	—	882	938	—	—	—	—	—	—
·000415	·00006	—	—	—	18	—	917	975	—	—	—	—	—	—
·000691	·0001	—	—	—	18	—	995	1058	—	—	—	—	—	—
·00138	·0002	—	—	—	18	—	1128	1199	—	—	—	—	—	—
·00415	·0006	—	—	—	18	—	1222	1299	—	—	—	—	—	—
·00691	·001	—	—	—	18	—	1221	1298	—	—	—	—	—	—
·0138	·002	—	—	—	18	—	1199	1274	—	—	—	—	—	—
·0415	·006	—	—	—	18	—	1124	1195	—	—	—	—	—	—
·0691	·01	—	—	—	18	·0249	1083	1151	—	—	—	—	—	—
—	·029	—	—	—	—	—	—	—	·302[2]	—	—	—	—	—
·207	·03	—	—	—	18	—	989	1051	—	—	—	—	—	—
·344	·05	1·0026	15	—	18	—	942	1001	—	—	—	—	—	—
—	·074	—	—	—	—	—	—	—	·372	—	—	—	—	—
·687	·1	1·0060	15	—	18	—	879	934	—	—	—	—	—	—
—	·151	—	—	—	—	—	—	—	·377	—	—	—	—	—
—	·441	—	—	—	—	—	—	—	·434	—	—	—	—	—
3·354	·5	1·0306	15	—	18	·0227	728	774	—	—	—	—	—	—
—	·764	—	—	—	—	—	—	—	·437	—	—	—	—	—
6·522	1·	1·0600	15	—	18	·0219	660	702	·4	—	1·	809[3]	17·6	—
—	1·607	—	—	—	—	—	—	—	·416	—	—	—	—	—
12·39	2·	1·1162	15	—	18	·0211	584	620	—	—	—	—	—	—
—	3·	—	—	—	18	·0210	517	550	—	—	—	—	—	—
—	3·147	—	—	—	—	—	—	—	·404	—	—	—	—	—
27·21	5·	1·2702	15	—	18	·0216	403	428	—	—	—	—	—	—
—	8·112	—	—	—	—	—	—	—	·341	—	—	—	—	—
46·14	10·	1·4959	15	—	18	·0285	169	180	—	—	—	—	—	—
·407	·059	1·0032	15	52[4]	18	—	874	929	—	—	—	—	—	—
·810	·118	1·0073	15	97	18	—	820	874	—	—	—	—	—	—
1·608	·236	1·0147	15	181	18	—	767	815	—	—	—	—	—	—
3·171	·472	1·0289	15	334	18	—	707	751	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

[3] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

[4] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

LITHIUM CARBONATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ Li_2CO_3, 37·02.

·00648	·00175	—	—	—	—	—	830 [1]	882	—	—	—	—	—	—
·0111	·0030	—	—	—	—	—	790	840	—	—	—	—	—	—
·0148	·0040	—	—	—	—	—	780	829	—	—	—	—	—	—
·503	·136	—	—	—	—	—	—	—	·593 [2]	—	—	—	—	—
—	·232	—	—	—	—	—	—	—	·582	—	—	—	—	—

[1] Vicentini, *Atti dell'Accad. di Torino*, vol. xx. p. 688.
[2] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

SODIUM CARBONATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ Na_2CO_3, 53·04.

·000053	·00001	—	—	—	18	—	697 [1]	740	—	—	—	—	—	—
·000106	·00002	—	—	—	18	—	715	760	—	—	—	—	—	—
·000318	·00006	—	—	—	18	—	790	840	—	—	—	—	—	—
·00053	·0001	—	—	—	18	—	874	929	—	—	—	—	—	—
·00106	·0002	—	—	—	18	—	988	1050	—	—	—	—	—	—
·00318	·0006	—	—	—	18	—	1046	1112	—	—	—	—	—	—
·0053	·001	—	—	—	18	—	1037	1102	—	—	—	—	—	—
·0106	·002	—	—	—	18	—	1010	1073	—	—	—	—	—	—
·0318	·006	—	—	—	18	—	956	1016	—	—	—	—	—	—
·053	·01	—	—	—	18	·0265	899	955	—	—	—	—	—	—
·159	·03	—	—	—	18	—	799	850	—	—	—	—	—	—
·264	·05	1·0019	15	—	18	—	751	798	—	—	—	—	—	—
·5	·093	—	—	—	—	—	—	—	·474 [3]	—	—	—	—	—
·528	·1	1·0046	15	—	18	—	682	725	—	—	—	—	—	—
—	·189	—	—	—	—	—	—	—	·519	—	—	—	—	—
2·592	·5	1·0271	15	—	18	·0244	510	542	—	—	—	—	—	—
5·0	·985	—	—	—	—	—	—	—	·548	—	—	—	—	—
5·038	1·	1·0529	15	—	18	·0252	427	454	—	—	—	—	—	—
—	2·844	—	—	—	—	—	—	—	·530	—	—	—	—	—
13·86	3·	1·1479	15	—	18	·0289	254	270	—	—	—	—	—	—
·659	·125	1·0060	15	79 [2]	18	—	632	672	—	—	—	—	—	—
1·307	·25	1·0137	15	142	18	—	568	603	—	—	—	—	—	—
2·592	·5	1·0271	15	248	18	—	496	527	—	—	—	—	—	—
5·038	1·	1·0529	15	433	18	—	433	460	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.
[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.
[3] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

POTASSIUM CHROMATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ K_2CrO_4, 97·33.

·638	·066	1·0044	19·5°	60·1 [1]	18°	—	910	967	—	—°	1·349 [3]	882	20°	—
1·270	·132	1·0101	19·5	113·0	18	—	856	909	—	—	2·363	802	20	—
2·515	·264	1·0203	19·5	212·0	18	—	803	853	—	—	4·407	620	20	—
4·932	·528	1·0402	19·5	396·0	18	—	750	797	—	—	—	—	—	—
9·50	—	—	—	—	—	—	—	—	·512 [2]	—	—	—	—	—

[1] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.
[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 371.
[3] Sprung, *Pogg. Annal.* vol. clix. p. 1.

AMMONIUM CHROMATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $(NH_4)_2CrO_4$, 76·24.

—	·0634	—	—	52 [1]	18	—	820	871	—	—	—	—	—	—
—	·1268	—	—	97	18	—	765	813	—	—	—	—	—	—
—	·2536	—	—	177	18	—	698	742	—	—	—	—	—	—
—	·517	—	—	318	18	—	615	653	—	—	—	—	—	—

[1] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

POTASSIUM BICHROMATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $K_2Cr_2O_7$, 147·52.

1·033	·0706	1·0073	19·5	62 [1]	18	—	878	933	—	—	—	—	—	—
2·050	·1413	1·0153	19·5	117	18	—	829	880	—	—	—	—	—	—
4·040	·2826	1·0303	19·5	208	18	—	736	782	—	—	—	—	—	—
6·390	—	—	—	—	—	—	—	—	·502 [2]	—	—	—	—	—
7·891	·5652	1·0553	19·5	415	18	—	734	780	—	—	—	—	—	—

[1] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.
[2] Hittorf, *Pogg. Annal.* vol. cvi. p. 371.

AMMONIUM BICHROMATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $(NH_4)_2Cr_2O_7$, 126·44.

—	·0883	—	—	72·7 [1]	18	—	823	874	—	—	—	—	—	—
—	·1767	—	—	133·0	18	—	752	799	—	—	—	—	—	—
—	·3534	—	—	252·0	18	—	713	757	—	—	—	—	—	—
—	·7068	—	—	472·0	18	—	667	708	—	—	—	—	—	—

[1] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

Equivalent Gramme Molecule, HCN, 26·98.

·084	·0312	—	—	·108 [1]	25	—	—	4·88 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 304.
·168	·0625	—	—	·101	25	—	—	4·56	—	—	—	—	—	—	[2] At 25°.
·337	·125	—	—	·090	25	—	—	4·06	—	—	—	—	—	—	
·675	·25	—	—	·077	25	—	—	3·48	—	—	—	—	—	—	

POTASSIUM CYANIDE.
Equivalent Gramme Molecule, KCN, 65·02.

·946	—	—	—	—	—	—	—	—	·47 [2]	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 149.
3·20	·5	1·0154	15	488 [1]	18	·0208	976	1037	—	—	—	—	—	—	[2] Hittorf, *Pogg. Annal.* vol. cvi.
6·30	1·	1·0312	15	938	18	·0195	938	997	—	—	—	—	—	—	
11·55	—	—	—	—	—	—	—	—	·457	—	—	—	—	—	

SULPHOCYANIC ACID.
Equivalent Gramme Molecule, HCNS, 58·96.

·00145	·000244	—	—	84·1 [1]	25	—	—	3797 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 305.
·0029	·000488	—	—	85·8	25	—	—	3874	—	—	—	—	—	—	[2] At 25°.
·0058	·000976	—	—	86·3	25	—	—	3897	—	—	—	—	—	—	
·0115	·00195	—	—	86·8	25	—	—	3919	—	—	—	—	—	—	
·023	·0039	—	—	86·5	25	—	—	3905	—	—	—	—	—	—	
·046	·0078	—	—	86·5	25	—	—	3905	—	—	—	—	—	—	
·092	·0156	—	—	85·2	25	—	—	3847	—	—	—	—	—	—	
·184	·0312	—	—	84·2	25	—	—	3802	—	—	—	—	—	—	
—	·0625	—	—	82·8	25	—	—	3739	—	—	—	—	—	—	
—	·125	—	—	81·2	25	—	—	3666	—	—	—	—	—	—	
—	·25	—	—	79·3	25	—	—	3581	—	—	—	—	—	—	
—	·5	—	—	76·7	25	—	—	3463	—	—	—	—	—	—	

HYDROFERROCYANIC ACID.
Equivalent Gramme Molecule, $\frac{1}{4}$ H_4FeCy_6, 53·95.

·00131	·000244	—	—	80·4 [1]	25	—	—	3630 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 307.
·00262	·000488	—	—	76·2	25	—	—	3440	—	—	—	—	—	—	[2] At 25°.
·00525	·000976	—	—	72·0	25	—	—	3251	—	—	—	—	—	—	
·0105	·00195	—	—	67·1	25	—	—	3030	—	—	—	—	—	—	
·0210	·0039	—	—	62·7	25	—	—	2831	—	—	—	—	—	—	
·0421	·0078	—	—	58·6	25	—	—	2646	—	—	—	—	—	—	
·0841	·0156	—	—	55·1	25	—	—	2488	—	—	—	—	—	—	

Formic Acid.

Equivalent Gramme Molecule, HCOOH, 46.

			°		°					°			°	
·00225	·000488	—	—	36·00 [1]	25	—	—	1622 [2]	—	—	—	—	—	—
·0045	·000976	—	—	29·04	25	—	—	1311	—	—	—	—	—	—
·0090	·00195	—	—	22·54	25	—	—	1018	—	—	—	—	—	—
·0180	·0039	—	—	17·00	25	—	—	768	—	—	—	—	—	—
·0359	·0078	—	—	12·58	25	—	—	568	—	—	—	—	—	—
·0718	·0156	—	—	9·18	25	—	—	414	—	—	—	—	—	—
·1435	·0312	—	—	6·63	25	—	—	299	—	—	—	—	—	—
·287	·0625	—	—	4·79	25	—	—	217	—	—	·125 [3]	1087	25	—
·574	·125	1·0015	25	3·43	25	—	—	155	—	—	·25	1083	25	—
—	·25	1·0030	25	2·46	25	—	—	111	—	—	·5	1075	25	—
—	·5	1·0058	25	1·76	25	—	—	79	—	—	1·0	1060	25	—
·0046	·001	—	—	103 [4]	17	—	—	1405	—	—	—	—	—	—
·0092	·002	—	—	77·8	17	—	—	1061	—	—	—	—	—	—
·046	·01	—	—	38·4	17	·018	—	524	—	—	—	—	—	—
·115	·025	—	—	24·9	17	—	—	340	—	—	—	—	—	—
·23	·05	—	—	17·9	17	—	—	245	—	—	—	—	—	—
·46	·1	—	—	12·9	17	—	—	176	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 445.

[2] At 25°.

[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 749.

[4] Berthelot, *Annales de Chimie*, series 6, vol. xxiii. p. 39.

Potassium Formate.

Equivalent Gramme Molecule, HCOOK, 84·13.

·0082	·000976	—	—	120·1 [1]	25	—	—	1277 [3]	—	—	—	—	—	—
·0164	·00195	—	—	117·3	25	—	—	1247	—	—	—	—	—	—
·0328	·0039	—	—	114·7	25	—	—	1219	—	—	—	—	—	—
·0655	·0078	—	—	112·3	25	—	—	1194	—	—	—	—	—	—
·131	·0156	—	—	108·8	25	—	—	1156	—	—	—	—	—	—
·262	·0312	—	—	105·8	25	—	—	1124	—	—	—	—	—	—
·0042	·0005	—	—	95 [2]	17	—	—	1341	—	—	—	—	—	—
·0168	·002	—	—	91·5	17	—	—	1291	—	—	—	—	—	—
·042	·005	—	—	87·6	17	·023	—	1236	—	—	—	—	—	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 102.

[2] Berthelot, *Annales de Chimie*, vol. xxiii. p. 40.

[3] At 25°.

Sodium Formate.

Equivalent Gramme Molecule, HCOONa, 68·04.

·0066	·000976	—	—	98·9 [1]	25	—	—	1051 [2]	—	—	—	—	—	—
·0132	·00195	—	—	96·9	25	—	—	1030	—	—	—	—	—	—
·0265	·0039	—	—	94·7	25	—	—	1007	—	—	·125 [3]	1068	25	—

[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 99.

·106	·0156	—	—	89·0	25	—	—	946	—	—	·5	998	25	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 750.
·212	·0312	—	—	85·8	25	—	—	912	—	—	1·0	906	25	—	
							LITHIUM FORMATE. Equivalent Gramme Molecule, HCOOLi, 52·02.								
·00505	·000976	—	—	88·1 [1]	25	—	—	936 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 103.
·0101	·00195	—	—	85·8	25	—	—	912	—	—	—	—	—	—	
·0202	·0039	—	—	83·4	25	—	—	886	—	—	—	—	—	—	
·0405	·0078	—	—	80·8	25	—	—	859	—	—	—	—	—	—	
·081	·0156	—	—	77·9	25	—	—	828	—	—	—	—	—	—	[2] At 25°.
·162	·0312	—	—	75·0	25	—	—	797	—	—	—	—	—	—	
							ACETIC ACID. Equivalent Gramme Molecule, CH_3COOH, 60.								
·00146	·000244	—	—	19·37 [1]	25	—	—	785	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 444.
·00292	·000488	—	—	14·48	25	—	—	586	—	—	—	—	—	—	
·00585	·000976	—	—	10·48	25	—	—	424	—	—	—	—	—	—	
·0117	·00195	—	—	7·77	25	—	—	314	—	—	—	—	—	—	
·0234	·0039	—	—	5·66	25	—	—	229	—	—	—	—	—	—	[2] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 749.
·0468	·0078	—	—	4·08	25	—	—	166	—	—	—	—	—	—	
·0935	·0156	—	—	2·94	25	—	—	119	—	—	—	—	—	—	
·187	·0312	—	—	2·123	25	—	—	86·1	—	—	—	—	—	—	
·374	·0625	—	—	1·514	25	—	—	61·4	—	—	—	—	—	—	[3] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 197.
·748	·125	1·0003	15	1·078	25	—	—	43·7	—	—	·125	1074 [2]	25	—	
1·494	·25	1·0014	15	·756	25	—	—	30·6	—	—	·25	1060	25	—	
2·982	·5	1·0036	15	·520	25	—	—	21·1	—	—	·5	1031	25	—	
—	—	—	—	—	—	—	—	—	—	—	1·0	982	25	—	
·00006	·00001	—	—	—	18	—	1304 [3]	1386	—	—	—	—	—	—	
·00012	·00002	—	—	—	18	—	1328	1412	—	—	—	—	—	—	
·00036	·00006	—	—	—	18	—	1133	1204	—	—	—	—	—	—	
·0006	·0001	—	—	—	18	—	995	1058	—	—	—	—	—	—	
·0012	·0002	—	—	—	18	—	796	846	—	—	—	—	—	—	
·0036	·0006	—	—	—	18	—	470	500	—	—	—	—	—	—	
·006	·001	—	—	—	18	—	380	404	—	—	—	—	—	—	
·012	·002	—	—	—	18	—	283	301	—	—	—	—	—	—	
·036	·006	—	—	—	18	—	170	181	—	—	—	—	—	—	
·06	·01	—	—	—	18	—	132	140	—	—	—	—	—	—	

ACETIC ACID—*continued.*

Equivalent Gramme Molecule, CH_3COOH, 60.

			°		°					°			°	
·18	·03	—	—	—	18	—	79	84	—	—	—	—	—	—
·30	·05	—	—	—	18	—	62	66	—	—	—	—	—	—
·60	·1	1·0002	15	—	18	—	43	46	—	—	—	—	—	—
2·98	·5	1·0036	15	—	18	—	19	20·2	—	—	—	—	—	—
5·95	1·	1·0080	15	—	18	—	12	12·7	—	—	—	—	—	—
17·56	3·	1·0246	15	—	18	—	5·2	5·5	—	—	—	—	—	—
28·87	5·	1·0389	15	—	18	—	2·6	2·8	—	—	—	—	—	—
56·39	10·	1·0644	15	—	18	—	·5	·53	—	—	—	—	—	—
·006	·001	—	—	35·0 [4]	17	—	—	425	—	—	—	—	—	—
·012	·002	—	—	25·2	17	—	—	306	—	—	—	—	—	—
·030	·005	—	—	16·2	17	—	—	196	—	—	—	—	—	—
·060	·01	—	—	11·6	17	·018	—	141	—	—	—	—	—	—

[4] Berthelot, *Annales de Chimie*, vol. xxiii. p. 43.

POTASSIUM ACETATE.

Equivalent Gramme Molecule, CH_3COOK, 98·13.

·000098	·00001	—	—	—	18	—	939 [1]	998	—	—	—	—	—	—
·000196	·00002	—	—	—	18	—	943	1002	—	—	—	—	—	—
·000588	·00006	—	—	—	18	—	935	994	—	—	—	—	—	—
·00098	·0001	—	—	—	18	—	934	993	—	—	—	—	—	—
·00196	·0002	—	—	—	18	—	933	992	—	—	—	—	—	—
·00588	·0006	—	—	—	18	—	923	981	—	—	—	—	—	—
·0098	·001	—	—	—	18	—	919	977	—	—	—	—	—	—
·0196	·002	—	—	—	18	—	913	970	—	—	—	—	—	—
·0588	·006	—	—	—	18	—	891	947	—	—	—	—	—	—
·098	·01	—	—	—	18	·0229	879	934	—	—	—	—	—	—
·294	·03	—	—	—	18	—	841	894	—	—	1·	735 [3]	17·6	—
—	·05	—	—	—	18	—	820	872	—	—	—	—	—	—
—	·1	—	—	—	18	—	784	833	—	—	—	—	—	—
1·057	·114	1·0051	14	—	—	—	—	—	·324 [2]	—	—	—	—	—
—	·5	—	—	—	18	·0224	671	713	—	—	—	—	—	—
9·37	1·	1·0467	18·6	—	18	·0220	594	631	—	—	—	—	—	—
—	3·	—	—	—	18	·0227	381	405	—	—	—	—	—	—
—	5·	—	—	—	18	·0252	240	255	—	—	—	—	—	—
42·7	5·4	1·2396	11	—	—	—	—	—	·325	—	—	—	—	—
	10·	—	—	—	18	·0421	30	32	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 195.

[2] Hittorf, *Pogg. Annal.* vol. cii. p. 42.

[3] Arrhenius, *Zeitschrift für Physik. Chemie*, vol. i. p. 295.

·0191	·00195	—	—	103·1	25	—	—	934	—	—	—	—	—	—	Ostwald, *Zeitschrift für Physik Chemie*, vol. i. p. 102.
·0382	·0039	—	—	100·4	25	—	—	915	—	—	—	—	—	—	
·0765	·0078	—	—	98·2	25	—	—	900	—	—	—	—	—	—	
·153	·0156	—	—	95·4	25	—	—	874	—	—	—	—	—	—	[5] Berthelot, *Annales de Chimie*, vol. xxiii. p. 43.
·306	·0312	—	—	92·9	25	—	—	851	—	—	—	—	—	—	
·0049	·0005	—	—	83·6[5]	17	—	—	1019	—	—	—	—	—	—	
·0196	·002	—	—	80·5	17	—	—	982	—	—	—	—	—	—	
·0294	·0033	—	—	78·0	17	—	—	951	—	—	—	—	—	—	
·049	·005	—	—	77·2	17	—	—	942	—	—	—	—	—	—	
·059	·0066	—	—	76·5	17	—	—	933	—	—	—	—	—	—	
·098	·01	—	—	75·4	17	—	—	920	—	—	—	—	—	—	

SODIUM ACETATE.

Equivalent Gramme Molecule, CH_3COONa, 82·04.

1·17	·142	1·0062	11	—	—	—	—	—	·443[3]	—	—	—	—	—	
2·36	·288	1·0125	5·5	—	—	—	—	—	·424	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 150.
—	·5	—	—	233[1]	18	·0253	466	495	—	—	—	—	—	—	
—	1·	—	—	389	18	·0255	389	413	—	—	·125	1047[4]	25	—	
12·22	1·6	1·0661	13	—	—	—	—	—	·421	—	·25	1003	25	—	[2] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 99.
—	2·	—	—	561	18	·0275	280	297	—	—	·5	926	25	—	
—	3·	—	—	609	18	·0306	203	215	—	—	1·	785	25	—	
26·26	3·64	1·1455	7·7	—	—	—	—	—	·415	—	—	—	—	—	
—	4·	—	—	575	18	·0340	119	126	—	—	—	—	—	—	[3] Hittorf, *Pogg. Annal*, vol. cvi. p. 379.
—	5·	—	—	495	18	·0410	99	105	—	—	—	—	—	—	
·008	·000976	—	—	84·9[2]	25	—	—	768	—	—	—	—	—	—	
·016	·00195	—	—	83·3	25	—	—	754	—	—	—	—	—	—	[4] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 750.
·032	·0039	—	—	81·2	25	—	—	735	—	—	—	—	—	—	
·064	·0078	—	—	79·0	25	—	—	715	—	—	—	—	—	—	
·128	·0156	—	—	76·4	25	—	—	691	—	—	—	—	—	—	
·256	·0312	—	—	73·6	25	—	—	666	—	—	—	—	—	—	

MONOCHLORACETIC ACID.

Equivalent Gramme Molecule, $CH_2ClCOOH$, 94·46.

·0023	·000244	—	—	68·69[1]	25	—	—	3102[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 446.
·0046	·000488	—	—	63·48	25	—	—	2866	—	—	—	—	—	—	
·0092	·000976	—	—	55·64	25	—	—	2512	—	—	—	—	—	—	
·0184	·00195	—	—	46·75	25	—	—	2111	—	—	—	—	—	—	[2] At 25°.

MONOCHLORACETIC ACID—*continued*.

Equivalent Gramme Molecule, $CH_2ClCOOH$, 94·46.

			°		°					°			°	
0368	·0039	—	—	37·81	25	—	—	1707	—	—	—	—	—	—
0735	·0078	—	—	29·61	25	—	—	1337	—	—	—	—	—	—
·147	·0156	—	—	22·85	25	—	—	1032	—	—	—	—	—	—
·294	·0312	—	—	17·29	25	—	—	781	—	—	—	—	—	—
·588	·0625	—	—	12·86	25	—	—	578	—	—	—	—	—	—
—	·125	—	—	9·53	25	—	—	430	—	—	—	—	—	—
—	·25	—	—	6·98	24	—	—	316	—	—	—	—	—	—
—	·5	—	—	4·99	25	—	—	179	—	—	—	—	—	—

DICHLORACETIC ACID.

Equivalent Gramme Molecule, $CHCl_2COOH$, 128·92.

·00312	·000244	—	—	79·28 [1]	25	—	—	3600 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 446.
·00625	·000488	—	—	80·94	25	—	—	3651	—	—	—	—	—	—	[2] At 25°.
·0125	·000976	—	—	80·48	25	—	—	3636	—	—	—	—	—	—	
·025	·00195	—	—	79·70	25	—	—	3601	—	—	—	—	—	—	
·050	·0039	—	—	76·30	25	—	—	3442	—	—	—	—	—	—	
·100	·0078	—	—	72·52	25	—	—	3271	—	—	—	—	—	—	
·200	·0156	—	—	67·56	25	—	—	3043	—	—	—	—	—	—	
·400	·0312	—	—	60·30	25	—	—	2720	—	—	—	—	—	—	
·800	·0625	—	—	52·08	25	—	—	2356	—	—	—	—	—	—	
—	·125	—	—	43·03	25	—	—	1912	—	—	—	—	—	—	
—	·25	—	—	34·42	25	—	—	1550	—	—	—	—	—	—	
—	·5	—	—	25·75	25	—	—	1161	—	—	—	—	—	—	

TRICHLORACETIC ACID.

Equivalent Gramme Molecule, $CCl_3CO{\cdot}OH$, 163·38.

·00398	·000244	—	—	77·84 [1]	25	—	—	3515 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 322.
·00795	·000488	—	—	79·10	25	—	—	3572	—	—	—	—	—	—	[2] At 25°.
·0159	·000976	—	—	79·68	25	—	—	3598	—	—	—	—	—	—	
·0318	·00195	—	—	79·58	25	—	—	3593	—	—	—	—	—	—	
·0635	·0039	—	—	79·12	25	—	—	3572	—	—	—	—	—	—	
·127	·0078	—	—	79·00	25	—	—	3567	—	—	—	—	—	—	
·254	·0156	—	—	78·55	25	—	—	3547	—	—	—	—	—	—	
·508	·0312	—	—	76·95	25	—	—	3475	—	—	—	—	—	—	

				[illegible]	25			3369							
—	·125	—	—	71·14	25	—	—	3212	—	—	—	—	—	—	
—	·25	—	—	65·63	25	—	—	2963	—	—	—	—	—	—	
—	·5	—	—	57·56	25	—	—	2599	—	—	—	—	—	—	

MONOBROMACETIC ACID.

Equivalent Gramme Molecule, $CH_2BrCOOH$, 138·95.

·00338	·000244	—	—	69·97 [1]	25	—	—	3159 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 322.
·00675	·000488	—	—	64·02	25	—	—	2891	—	—	—	—	—	—	[2] At 25°.
·0135	·000976	—	—	55·47	25	—	—	2505	—	—	—	—	—	—	
·027	·00195	—	—	46·14	25	—	—	2083	—	—	—	—	—	—	
·054	·0039	—	—	36·83	25	—	—	1663	—	—	—	—	—	—	
·108	·0078	—	—	28·52	25	—	—	1288	—	—	—	—	—	—	
·216	·0156	—	—	21·62	25	—	—	976	—	—	—	—	—	—	
·432	·0312	—	—	16·12	25	—	—	728	—	—	—	—	—	—	
·863	·0625	—	—	11·90	25	—	—	537	—	—	—	—	—	—	
—	·125	—	—	8·65	25	—	—	391	—	—	—	—	—	—	

POTASSIUM TRICHLORACETATE.

Equivalent Gramme Molecule, CCl_3COOK, 201·51.

·0196	·000976	—	—	101·9 [1]	25	—	—	1083 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 103.
·0392	·00195	—	—	99·5	25	—	—	1058	—	—	—	—	—	—	[2] At 25°.
·0785	·0039	—	—	96·8	25	—	—	1029	—	—	—	—	—	—	
·157	·0078	—	—	94·3	25	—	—	1002	—	—	—	—	—	—	
·314	·0156	—	—	91·7	25	—	—	975	—	—	—	—	—	—	
·628	·0312	—	—	88·5	25	—	—	941	—	—	—	—	—	—	

SODIUM TRICHLORACETATE.

Equivalent Gramme Molecule, CCl_3COONa, 185·42.

·018	·000976	—	—	80·7 [1]	25	—	—	856 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 100.
·036	·00195	—	—	78·7	25	—	—	837	—	—	—	—	—	—	[2] At 25°.
·072	·0039	—	—	76·8	25	—	—	816	—	—	—	—	—	—	
·144	·0078	—	—	74·8	25	—	—	795	—	—	—	—	—	—	
·288	·0156	—	—	72·6	25	—	—	772	—	—	—	—	—	—	
·576	·0312	—	—	70·0	25	—	—	744	—	—	—	—	—	—	

LITHIUM TRICHLORACETATE.

Equivalent Gramme Molecule, CCl_3COOLi, 169·4.

			°		°					°			°		
·0165	·000976	—	—	70·2 [1]	25	—	—	746 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 104.
·033	·00195	—	—	68·1	25	—	—	724	—	—	—	—	—	—	
·066	·0039	—	—	66·0	25	—	—	702	—	—	—	—	—	—	
·132	·0078	—	—	64·2	25	—	—	682	—	—	—	—	—	—	[2] At 25°.
·264	·0156	—	—	62·0	25	—	—	659	—	—	—	—	—	—	
·528	·0312	—	—	59·9	25	—	—	637	—	—	—	—	—	—	

PROPIONIC ACID.

Equivalent Gramme Molecule, C_2H_5COOH, 74.

·0018	·000244	—	—	18·2 [1]	25	—	—	822 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 317.
·0036	·000448	—	—	13·19	25	—	—	596	—	—	—	—	—	—	
·0072	·000976	—	—	9·56	25	—	—	432	—	—	—	—	—	—	
·0144	·00195	—	—	6·88	25	—	—	310	—	—	—	—	—	—	[2] At 25°.
·0289	·0039	—	—	4·92	25	—	—	222	—	—	—	—	—	—	
·0578	·0078	—	—	3·50	25	—	—	158	—	—	—	—	—	—	
·1155	·0156	—	—	2·49	25	—	—	112	—	—	—	—	—	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 749.
·231	·0312	—	—	1·767	25	—	—	80	—	—	—	—	—	—	
·462	·0625	—	—	1·247	25	—	—	56	—	—	·125	1065 [3]	25	—	
·924	·125	1·0011	25	·871	25	—	—	39	—	—	·25	1044	25	—	
1·846	·25	1·0019	25	·601	25	—	—	27	—	—	·5	994	25	—	
3·687	·5	1·0035	25	·403	25	—	—	18	—	—	1·	913	25	—	

POTASSIUM PROPIONATE.

Equivalent Gramme Molecule, C_2H_5COOK, 112·13.

·0110	·000976	—	—	103·0 [1]	25	—	—	1095 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 102.
·0219	·00195	—	—	101·1	25	—	—	1064	—	—	—	—	—	—	
·0438	·0039	—	—	97·4	25	—	—	1035	—	—	—	—	—	—	
·0875	·0078	—	—	94·9	25	—	—	1009	—	—	—	—	—	—	[2] At 25°.
·175	·0156	—	—	92·1	25	—	—	979	—	—	—	—	—	—	
·350	·0312	—	—	89·0	25	—	—	946	—	—	—	—	—	—	

SODIUM PROPIONATE.

Equivalent Gramme Molecule, C_2H_5COONa, 96·04.

·0094	·000976	—	—	80·4 [1]	25	—	—	854 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 99.
·0188	·00195	—	—	78·8	25	—	—	837	—	—	·125	1036 [3]	25	—	
·0375	·0039	—	—	76·5	25	—	—	813	—	—	·25	983	25	—	[2] At 25°.
·075	·0078	—	—	74·5	25	—	—	792	—	—	·5	885	25	—	
·150	·0156	—	—	71·9	25	—	—	764	—	—	1·	711	25	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 750.
·300	·0312	—	—	69·4	25	—	—	737	—	—	—	—	—	—	

LITHIUM PROPIONATE.

Equivalent Gramme Molecule, C_2H_5COOLi, 80·02.

·0078	·00976	—	—	69·5 [1]	25	—	—	739 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 104.
·0156	·00195	—	—	67·5	25	—	—	717	—	—	—	—	—	—	
·0312	·0039	—	—	65·5	25	—	—	696	—	—	—	—	—	—	
·0625	·0078	—	—	63·5	25	—	—	675	—	—	—	—	—	—	
·125	·0156	—	—	60·6	25	—	—	644	—	—	—	—	—	—	[2] At 25°.
·250	·0312	—	—	57·9	25	—	—	615	—	—	—	—	—	—	

A. BROMPROPIONIC ACID.

Equivalent Gramme Molecule, $C_2H_4BrCOOH$, 152·95.

·00372	·000244	—	—	68·9 [1]	—	—	—	3111 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 324.
·00745	·000488	—	—	62·2	—	—	—	2807	—	—	—	—	—	—	
·0149	·000976	—	—	53·7	—	—	—	2423	—	—	—	—	—	—	
·0298	·00195	—	—	44·7	—	—	—	2020	—	—	—	—	—	—	
·0595	·0039	—	—	36·1	—	—	—	1632	—	—	—	—	—	—	[2] At 25°.
·119	·0078	—	—	28·8	—	—	—	1299	—	—	—	—	—	—	
·238	·0156	—	—	22·6	—	—	—	1020	—	—	—	—	—	—	
·477	·0312	—	—	17·6	—	—	—	796	—	—	—	—	—	—	
—	·0625	—	—	13·7	—	—	—	619	—	—	—	—	—	—	
—	·125	—	—	10·5	—	—	—	475	—	—	—	—	—	—	
—	·25	—	—	7·9	—	—	—	355	—	—	—	—	—	—	
—	·5	—	—	5·6	—	—	—	252	—	—	—	—	—	—	

B. Iodopropionic Acid.

Equivalent Gramme Molecule, CH_2ICH_2COOH, 199·8.

			°		°					°			°		
·0049	·000244	—	—	36·0[1]	25	—	—	1628[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 325.
·0098	·000488	—	—	28·2	25	—	—	1272	—	—	—	—	—	—	
·0195	·000976	—	—	21·3	25	—	—	964	—	—	—	—	—	—	
·039	·00195	—	—	15·8	25	—	—	715	—	—	—	—	—	—	
·078	·0039	—	—	11·6	25	—	—	524	—	—	—	—	—	—	[2] At 25°.
·156	·0078	—	—	8·45	25	—	—	381	—	—	—	—	—	—	
·312	·0156	—	—	6·10	25	—	—	275	—	—	—	—	—	—	
·624	·0312	—	—	4·38	25	—	—	198	—	—	—	—	—	—	
—	·0625	—	—	3·12	25	—	—	141	—	—	—	—	—	—	
—	·125	—	—	2·22	25	—	—	100	—	—	—	—	—	—	
—	·25	—	—	1·53	25	—	—	69	—	—	—	—	—	—	

Butyric Acid.

Equivalent Gramme Molecule, C_3H_7COOH, 88.

·00214	·000244	—	—	18·0[1]	25	—	—	814[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxi. p. 444.
·00428	·000488	—	—	13·4	25	—	—	604	—	—	—	—	—	—	
·00855	·000976	—	—	9·74	25	—	—	440	—	—	—	—	—	—	
·0171	·00195	—	—	7·01	25	—	—	317	—	—	—	—	—	—	
·0342	·0039	—	—	5·04	25	—	—	228	—	—	—	—	—	—	[2] At 25°.
·0685	·0078	—	—	3·59	25	—	—	162	—	—	—	—	—	—	
·137	·0156	—	—	2·56	25	—	—	116	—	—	—	—	—	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 749.
·274	·0312	—	—	1·81	25	—	—	82	—	—	—	—	—	—	
·548	·0625	—	—	1·27	25	—	—	58	—	—	·125	1060[3]	25	—	
1·099	·125	1·0006	25	·88	25	—	—	40	—	—	·25	1027	25	—	
2·197	·25	1·0013	25	·60	25	—	—	27	—	—	·5	966	25	—	
4·390	·5	1·0022	25	·39	25	—	—	18	—	—	1·	854	25	—	

Potassium Butyrate.

Equivalent Gramme Molecule, C_3H_7COOK, 126·13.

·0122	·000976	—	—	100·3[1]	25	—	—	1066[2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 102.
·0245	·00195	—	—	97·4	25	—	—	1035	—	—	—	—	—	—	
·049	·0039	—	—	94·8	25	—	—	1008	—	—	—	—	—	—	
·098	·0078	—	—	92·5	25	—	—	983	—	—	—	—	—	—	
·196	·0156	—	—	89·0	25	—	—	946	—	—	—	—	—	—	[2] At 25°.
·393	·0312	—	—	86·3	25	—	—	917	—	—	—	—	—	—	

SODIUM BUTYRATE.

Equivalent Gramme Molecule, C_3H_7COONa, 110·04.

·0108	·000976	—	—	76·4 [1]	25	—	—	812 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 99.
·0215	·00195	—	—	75·0	25	—	—	797	—	—	·125	1025 [3]	25	—	
·043	·0039	—	—	73·4	25	—	—	780	—	—	·25	962	25	—	
·086	·0078	—	—	71·2	25	—	—	757	—	—	·5	845	25	—	[2] At 25°.
·172	·0156	—	—	68·9	25	—	—	732	—	—	1·	652	25	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 751.
·343	·0312	—	—	66·2	25	—	—	703	—	—	—	—	—	—	

LITHIUM BUTYRATE.

Equivalent Gramme Molecule, C_3H_7COOLi, 94·02.

·0091	·000976	—	—	66·5 [1]	25	—	—	707 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 104.
·0182	·00195	—	—	64·7	25	—	—	688	—	—	—	—	—	—	
·0365	·0039	—	—	63·0	25	—	—	670	—	—	—	—	—	—	
·073	·0078	—	—	60·8	25	—	—	646	—	—	—	—	—	—	
·146	·0156	—	—	58·2	25	—	—	619	—	—	—	—	—	—	[2] At 25°.
·293	·0312	—	—	55·5	25	—	—	590	—	—	—	—	—	—	

ISOBUTYRIC ACID.

Equivalent Gramme Molecule, C_3H_7COOH, 88.

·00215	·000244	—	—	17·62 [1]	25	—	—	797 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p 318.
·0043	·000488	—	—	12·97	25	—	—	587	—	—	—	—	—	—	
·0086	·000976	—	—	9·50	25	—	—	430	—	—	—	—	—	—	
·0172	·00195	—	—	6·86	25	—	—	310	—	—	—	—	—	—	
·0345	·0039	—	—	4·95	25	—	—	224	—	—	—	—	—	—	[2] At 25°.
·069	·0078	—	—	3·55	25	—	—	161	—	—	—	—	—	—	
·138	·0156	—	—	2·54	25	—	—	115	—	—	—	—	—	—	
·275	·0312	—	—	1·81	25	—	—	82	—	—	—	—	—	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 749.
·550	·0625	—	—	1·27	25	—	—	57	—	—	·125 [3]	1059	25	—	
1·100	·125	1·0004	25	·89	25	—	—	40	—	—	·25	1025	25	—	
2·198	·25	1·0008	25	·61	25	—	—	27·6	—	—	·5	968	25	—	
4·392	·5	1·0016	25	·39	25	—	—	17·6	—	—	1·	859	25	—	

Potassium Isobutyrate.

Equivalent Gramme Molecule, C_3H_7COOK, 126·13.

			°		°					°			°		
·0122	·000976	—	—	100·2[1]	25	—	—	1065[2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 102.
·0245	·00195	—	—	97·4	25	—	—	1035	—	—	—	—	—	—	
·049	·0039	—	—	94·9	25	—	—	1009	—	—	—	—	—	—	
·098	·0078	—	—	92·5	25	—	—	983	—	—	—	—	—	—	
·196	·0156	—	—	89·6	25	—	—	952	—	—	—	—	—	—	[2] At 25°.
·393	·0312	—	—	86·7	25	—	—	922	—	—	—	—	—	—	

Sodium Isobutyrate.

Equivalent Gramme Molecule, C_3H_7COONa, 110·04.

·0108	·000976	—	—	79·0[1]	25	—	—	840[2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 99.
·0215	·00195	—	—	76·6	25	—	—	814	—	—	·125[3]	1021	25	—	
·043	·0039	—	—	74·3	25	—	—	790	—	—	·25	956	25	—	
·086	·0078	—	—	71·6	25	—	—	761	—	—	·5	841	25	—	[2] At 25°.
·172	·0156	—	—	68·9	25	—	—	732	—	—	1·	649	25	—	[3] Reyher, *Zeitschrift für Physik. Chemie*, vol. ii. p. 751.
·343	·0312	—	—	66·0	25	—	—	701	—	—	—	—	—	—	

Lithium Isobutyrate.

Equivalent Gramme Molecule, C_3H_7COOLi, 94·02.

·0091	·000976	—	—	66·5[1]	25	—	—	707[2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie*, vol. i. p. 104.
·0182	·00195	—	—	64·8	25	—	—	689	—	—	—	—	—	—	
·0365	·0039	—	—	63·0	25	—	—	670	—	—	—	—	—	—	
·073	·0078	—	—	60·7	25	—	—	645	—	—	—	—	—	—	
·146	·0156	—	—	58·4	25	—	—	621	—	—	—	—	—	—	[2] At 25°.
·293	·0312	—	—	55·6	25	—	—	591	—	—	—	—	—	—	

Lactic Acid.

Equivalent Gramme Molecule, $CH_3C(OH)HCOOH$, 90.

·0022	·000244	—	—	44·0[1]	25	—	—	1987[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 328.
·0044	·000488	—	—	33·8	25	—	—	1526	—	—	—	—	—	—	
·0088	·000976	—	—	26·0	25	—	—	1174	—	—	—	—	—	—	
·0175	·00195	—	—	19·5	25	—	—	881	—	—	—	—	—	—	
·035	·0039	—	—	14·4	25	—	—	650	—	—	—	—	—	—	[2] At 25°.
·070	·0078	—	—	10·6	25	—	—	479	—	—	—	—	—	—	

·280	·0312	—	—	5·5	25	—	—	248	—	—	—	—	—	—	[3] Reyher, *Zeitschrift*
·560	·0625	—	—	3·9	25	—	—	177	—	—	—	—	—	—	*für Physik. Chemie,*
1·122	·125	1·0026	25	2·8	25	—	—	125	—	—	·125 [3]	1059	25	—	vol. ii. p. 749.
2·239	·25	1·0052	25	1·9	25	—	—	88	—	—	·25	1032	25	—	
4·455	·5	1·0103	25	1·3	25	—	—	60	—	—	1·	976	25	—	
											·5	874	25	—	

POTASSIUM LACTATE.

Equivalent Gramme Molecule, $CH_3C(OH)HCOOK$, 128·13.

·0125	·000976	—	—	102·6 [1]	25	—	—	1091 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie,* vol. i. p. 103.
·025	·00195	—	—	99·9	25	—	—	1062	—	—	—	—	—	—	
·050	·0039	—	—	97·5	25	—	—	1036	—	—	—	—	—	—	
·100	·0078	—	—	94·8	25	—	—	1008	—	—	—	—	—	—	
·200	·0156	—	—	91·9	25	—	—	977	—	—	—	—	—	—	[2] At 25°.
·400	·0312	—	—	88·9	25	—	—	945	—	—	—	—	—	—	

SODIUM LACTATE.

Equivalent Gramme Molecule, $CH_3C(OH)HCOONa$, 112·04.

·0110	·000976	—	—	81·1 [1]	25	—	—	862 [2]	—	—	—	—	—	—	[1] Ostwald, *Zeitschrift für Physik. Chemie,* vol. i. p. 100.
·0219	·00195	—	—	79·2	25	—	—	842	—	—	·125 [3]	1039	25	—	
·0438	·0039	—	—	77·1	25	—	—	820	—	—	·25	990	25	—	
·0875	·0078	—	—	74·6	25	—	—	793	—	—	·5	893	25	—	[2] At 25°.
·175	·0156	—	—	71·9	25	—	—	764	—	—	1·	729	25	—	[3] Reyher, *Zeitschrift für Physik. Chemie,* vol. ii. p. 751.
·349	·0312	—	—	69·4	25	—	—	738	—	—	—	—	—	—	

OXALIC ACID.

Equivalent Gramme Molecule, $\frac{1}{2}(COOH)_2$, 45.

·0011	·000244	—	—	59·2 [1]	25	—	—	2434	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie,* vol. xxxi. p. 457.
·0022	·000488	—	—	49·3	25	—	—	2027	—	—	—	—	—	—	
·0044	·000976	—	—	46·0	25	—	—	1889	—	—	—	—	—	—	
·0088	·00195	—	—	43·6	25	—	—	1792	—	—	—	—	—	—	
·0175	·0039	—	—	41·8	25	—	—	1717	—	—	—	—	—	—	
·035	·0078	—	—	39·9	25	—	—	1638	—	—	—	—	—	—	
·070	·0156	—	—	37·5	25	—	—	1542	—	—	—	—	—	—	
·140	·0312	—	—	34·5	25	—	—	1417	—	—	—	—	—	—	

OXALIC ACID—*continued*.

Equivalent Gramme Molecule, $\frac{1}{2}$ $(COOH)_2$, 45.

			°		°					°			°	
·280	·0625	—	—	30·7	25	—	—	1261	—	—	—	—	—	—
·560	·125	—	—	26·4	25	—	—	1085	—	—	—	—	—	—
—	·25	—	—	22·1	25	—	—	906	—	—	—	—	—	—
—	·5	—	—	17·9	25	·0142	—	736	—	—	—	—	—	—
—	1·	—	—	14·1	25	—	—	578	—	—	—	—	—	—
·280	·0625	—	—	75·8 [2]	18	—	1212	1288	—	—	—	—	—	—
·560	·125	—	—	131·3	18	—	1050	1116	—	—	—	—	—	—
—	·25	—	—	219·7	18	—	879	938	—	—	—	—	—	—
—	·5	—	—	356·0	18	—	713	758	—	—	—	—	—	—
·0009	·0002	—	—	185 [3]	20	—	—	2331	—	—	—	—	—	—
·009	·002	—	—	144	20	—	—	1814	—	—	—	—	—	—
·045	·01	—	—	128	20	—	—	1609	—	—	—	—	—	—
·090	·02	—	—	119	20	—	—	1506	—	—	—	—	—	—
·180	·04	—	—	110	20	—	—	1381	—	—	—	—	—	—

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Berthelot, *Annales de Chimie*, vol. xxiii. p. 49.

POTASSIUM OXALATE.

Equivalent Gramme Molecule, $\frac{1}{2}$ $(COOK)_2$, 83·13.

—	·5	—	—	373 [1]	18	·0214	746	793	—	—	—	—	—	—
—	1·	—	—	688	18	·0209	688	730	—	—	—	—	—	—
—	1·5	—	—	959	18	·0205	640	680	—	—	—	—	—	—
19·3	—	—	—	—	—	—	—	—	·441 [4]	—	—	—	—	—
—	·0625	—	—	56 [2]	18	—	896	953	—	—	—	—	—	—
—	·125	—	—	106	18	—	848	901	—	—	—	—	—	—
—	·25	—	—	198	18	—	792	842	—	—	—	—	—	—
—	·5	—	—	368	18	—	736	782	—	—	—	—	—	—
·0055	·00066	—	—	103·9 [3]	20	—	—	1186	—	—	—	—	—	—
·0068	·00082	—	—	103·7	20	—	—	1184	—	—	—	—	—	—
·0274	·0033	—	—	98·4	20	—	—	1124	—	—	—	—	—	—
·0548	·0066	—	—	94·9	20	·022	—	1084	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 150.

[2] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[3] Berthelot, *Annales de Chimie*, vol. xxiii. p. 50.

[4] Hittorf, *Pogg. Annal.* vol. cvi. p. 371.

Equivalent Gramme Molecule, $\frac{1}{2}$ $C_2H_2(OH)_2(COOH)_2$, 75.

·00182	·000244	—	—	94·8 [1]	25	—	—	2140 [3]	—	—	—	—	—	—
·00365	·000488	—	—	80·3	25	—	—	1813	—	—	—	—	—	—
·0073	·000976	—	—	67·0	25	—	—	1513	—	—	—	—	—	—
·0146	·00195	—	—	54·5	25	—	—	1230	—	—	—	—	—	—
·0292	·0039	—	—	43·1	25	—	—	973	—	—	—	—	—	—
·0585	·0078	—	—	33·1	25	—	—	747	—	—	—	—	—	—
·117	·0156	—	—	25·1	25	—	—	567	—	—	—	—	—	—
·234	·0312	—	—	18·7	25	—	—	422	—	—	—	—	—	—
·468	·0625	1·0016	15	13·7	25	—	—	309	—	—	—	—	—	—
·934	·125	1·0042	15	9·9	25	—	—	223	—	—	—	—	—	—
1·86	·25	1·0083	15	7·1	25	—	—	160	—	—	—	—	—	—
3·69	·5	1·0165	15	5·05	25	—	—	114	—	—	—	—	—	—
7·26	1·	1·0334	15	3·46	25	—	—	78	—	—	—	—	—	—
·0015	·0002	—	—	155 [2]	17	—	—	2144	—	—	—	—	—	—
·003	·0004	—	—	135	17	—	—	1867	—	—	—	—	—	—
·015	·002	—	—	88	17	—	—	1224	—	—	—	—	—	—
·030	·004	—	—	69·6	17	—	—	963	—	—	—	—	—	—
·075	·01	—	—	49·4	17	·020	—	683	—	—	—	—	—	—
·150	·02	—	—	37·0	17	—	—	512	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 340.

[2] Berthelot, *Annales de Chimie*, vol. xxiii. p. 89.

[3] At 25°.

Benzoic Acid.

Equivalent Gramme Molecule, C_6H_5COOH, 122.

·00298	·000244	—	—	31·7 [1]	25	—	—	1433 [3]	—	—	—	—	—	—
·00595	·000488	—	—	24·6	25	—	—	1111	—	—	—	—	—	—
·0119	·000976	—	—	18·4	25	—	—	832	—	—	—	—	—	—
·0238	·00195	—	—	13·6	25	—	—	615	—	—	—	—	—	—
·0475	·0039	—	—	9·95	25	—	—	449	—	—	—	—	—	—
·095	·0078	—	—	7·20	25	—	—	325	—	—	—	—	—	—
·190	·0156	—	—	5·20	25	—	—	235	—	—	—	—	—	—
·00122	·0001	—	—	60·2 [2]	17	—	—	833	—	—	—	—	—	—
·0244	·002	—	—	44·4	17	—	—	614	—	—	—	—	—	—
·061	·005	—	—	29·0	17	—	—	401	—	—	—	—	—	—
·122	·01	—	—	20·8	17	·020	—	288	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 343.

[2] Berthelot, *Annales de Chimie*, vol. xxiii. p. 44.

[3] At 25°.

SALICYLIC ACID.

Equivalent Gramme Molecule, $C_6H_4(OH)COOH$, 138.

			°		°					°			°	
·0034	·000244	—	—	66·6 [1]	25	—	—	3008 [3]	—	—	—	—	—	—
·0068	·000488	—	—	59·9	25	—	—	2704	—	—	—	—	—	—
·0135	·000976	—	—	51·2	25	—	—	2313	—	—	—	—	—	—
·027	·00195	—	—	41·8	25	—	—	1886	—	—	—	—	—	—
·054	·0039	—	—	32·3	25	—	—	1461	—	—	—	—	—	—
·108	·0078	—	—	25·1	25	—	—	1135	—	—	—	—	—	—
·216	·0156	—	—	19·1	25	—	—	863	—	—	—	—	—	—
·0138	·001	—	—	171·2 [2]	17	—	—	2367	—	—	—	—	—	—
·0345	·0025	—	—	128·7	17	—	—	1780	—	—	—	—	—	—
·069	·005	—	—	99·4	17	—	—	1375	—	—	—	—	—	—
·138	·01	—	—	75·1	17	·020	—	1039	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 344.

[2] Berthelot, *Annales de Chimie*, vol. xxiii. p. 80.

[3] At 25°.

METAOXYBENZOIC ACID.

Equivalent Gramme Molecule, $C_6H_4(OH)COOH$, 138.

·0034	·000244	—	—	34·3 [1]	25	—	—	1550 [3]	—	—	—	—	—	—
·0068	·000488	—	—	26·8	25	—	—	1211	—	—	—	—	—	—
·0135	·000976	—	—	20·3	25	—	—	918	—	—	—	—	—	—
·027	·00195	—	—	15·2	25	—	—	686	—	—	—	—	—	—
·054	·0039	—	—	11·2	25	—	—	507	—	—	—	—	—	—
·108	·0078	—	—	8·24	25	—	—	372	—	—	—	—	—	—
·216	·0156	—	—	5·99	25	—	—	271	—	—	—	—	—	—
·432	·0312	—	—	4·31	25	—	—	195	—	—	—	—	—	—
·0138	·001	—	—	71·9 [2]	17	—	—	994	—	—	—	—	—	—
·0345	·0025	—	—	48·1	17	—	—	663	—	—	—	—	—	—
·069	·005	—	—	35·0	17	—	—	484	—	—	—	—	—	—
·138	·01	—	—	25·2	17	·020	—	349	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 345.

[2] Berthelot, *Annales de Chimie*, vol. xxiii. p. 82.

[3] At 25°.

PAROXYBENZOIC ACID.

Equivalent Gramme Molecule, $C_6H_4(OH)COOH$, 138.

·0034	·000244	—	—	22·8 [1]	25	—	—	1029 [2]	—	—	—	—	—	—
·0068	·000488	—	—	17·2	25	—	—	776	—	—	—	—	—	—
·0135	·000976	—	—	12·7	25	—	—	573	—	—	—	—	—	—
·027	·00195	—	—	9·2	25	—	—	416	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 345.

[2] At 25°.

·108	·0078	—	—	4·77	25	—	—	215	—	—	—	—	—	—	Berthelot, *Annales de Chimie*, vol. xxiii. p. 84.
·216	·0156	—	—	3·38	25	—	—	153	—	—	—	—	—	—	
·432	·0312	—	—	2·39	25	—	—	108	—	—	—	—	—	—	
·0138	·001	—	—	42·6 [3]	17	—	—	589	—	—	—	—	—	—	
·0345	·0025	—	—	28·0	17	—	—	387	—	—	—	—	—	—	
·069	·005	—	—	20·0	17	—	—	276	—	—	—	—	—	—	
·138	·01	—	—	14·3	17	·020	—	198	—	—	—	—	—	—	
ORTHONITROBENZOIC ACID.															
Equivalent Gramme Molecule, $C_6H_4(NO_2)COOH$, 167·04.															
·00405	·000244	—	—	72·6 [1]	25	—	—	3280 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 347.
·0081	·000488	—	—	70·9	25	—	—	3203	—	—	—	—	—	—	
·0162	·000976	—	—	67·2	25	—	—	3037	—	—	—	—	—	—	
·0325	·00195	—	—	61·8	25	—	—	2789	—	—	—	—	—	—	
·065	·0039	—	—	54·3	25	—	—	2453	—	—	—	—	—	—	[2] At 25°.
·130	·0078	—	—	45·9	25	—	—	2073	—	—	—	—	—	—	
·260	·0156	—	—	37·4	25	—	—	1688	—	—	—	—	—	—	
·521	·0312	—	—	29·3	25	—	—	1321	—	—	—	—	—	—	
METANITROBENZOIC ACID.															
Equivalent Gramme Molecule, $C_6H_4(NO_2)COOH$, 167·04.															
·00405	·000244	—	—	53·4 [1]	25	—	—	2410 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 347.
·0081	·000488	—	—	44·7	25	—	—	2021	—	—	—	—	—	—	
·0162	·000976	—	—	35·8	25	—	—	1616	—	—	—	—	—	—	
·0325	·00195	—	—	27·7	25	—	—	1250	—	—	—	—	—	—	
·065	·0039	—	—	20·8	25	—	—	934	—	—	—	—	—	—	[2] At 25°.
·130	·0078	—	—	15·3	25	—	—	691	—	—	—	—	—	—	
·260	·0156	—	—	11·2	25	—	—	505	—	—	—	—	—	—	
PARANITROBENZOIC ACID.															
Equivalent Gramme Molecule, $C_6H_4(NO_2)COOH$, 167·04.															
·00405	·000244	—	—	54·6 [1]	25	—	—	2464 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 348.
·0081	·000488	—	—	45·8	25	—	—	2069	—	—	—	—	—	—	[2] At 25°.
·0162	·000976	—	—	37·1	25	—	—	1676	—	—	—	—	—	—	
·0325	·00195	—	—	28·9	25	—	—	1307	—	—	—	—	—	—	

Orthochlorbenzoic Acid.

Equivalent Gramme Molecule, $C_6H_4ClCOOH$, 156·46.

			°		°					°			°	
·0038	·000244	—	—	67·4[1]	25	—	—	3046[2]	—	—	—	—	—	—
·0076	·000488	—	—	61·9	25	—	—	2794	—	—	—	—	—	—
·0152	·000976	—	—	53·8	25	—	—	2431	—	—	—	—	—	—
·0305	·00195	—	—	44·7	25	—	—	2018	—	—	—	—	—	—
·061	·0039	—	—	35·5	25	—	—	1605	—	—	—	—	—	—
·122	·0078	—	—	27·6	25	—	—	1246	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 349.

[2] At 25°.

Metachlorbenzoic Acid.

Equivalent Gramme Molecule, $C_6H_4ClCOOH$, 156·46.

·0038	·000244	—	—	43·6[1]	25	—	—	1971[2]	—	—	—	—	—	—
·0076	·000488	—	—	34·9	25	—	—	1577	—	—	—	—	—	—
·0152	·000976	—	—	20·9	25	—	—	946	—	—	—	—	—	—
·0305	·00195	—	—	20·4	25	—	—	921	—	—	—	—	—	—
·061	·0039	—	—	15·1	25	—	—	683	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxii. p. 349.

[2] At 25°.

Potassic Hydrate.

Equivalent Gramme Molecule, KHO, 56·13.

·000056	·00001	—	—	—	18	—	747[1]	794	—	—	—	—	—	—
·000112	·00002	—	—	—	18	—	845	898	—	—	—	—	—	—
·000336	·00006	—	—	—	18	—	1474	1567	—	—	—	—	—	—
·000561	·0001	—	—	—	18	—	1689	1795	—	—	—	—	—	—
·00112	·0002	—	—	—	18	—	1892	2011	—	—	—	—	—	—
·00336	·0006	—	—	—	18	—	2074	2205	—	—	—	—	—	—
·00561	·001	—	—	—	18	—	2110	2243	—	—	—	—	—	—
·0112	·002	—	—	—	18	—	2140	2275	—	—	—	—	—	—
·0336	·006	—	—	—	18	—	2141	2276	—	—	—	—	—	—
·0561	·01	—	—	—	18	·0194	2124	2258	—	—	—	—	—	—
·168	·03	—	—	—	18	—	2078	2209	—	—	—	—	—	—
·280	·05	1·0019	15	—	18	—	2045	2174	—	—	—	—	—	—
·558	·1	1·0047	15	—	18	—	1986	2111	—	—	—	—	—	—
—	·103	—	—	—	—	—	—	—	·742[4]	—	—	—	—	—
—	·190	—	—	—	—	—	—	—	·730	—	—	—	—	—
2·743	·5	1·0230	15	—	18	·0188	1841	1957	—	—	—	—	—	—
—	·804	—	—	—	—	—	—	—	·739	—	—	—	—	—
5·376	1·	1·0440	15	—	18	·0187	1718	1826	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 196.

[2] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 353.

[3] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[4] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

14·93	3·	1·1274	15	—	18	·0191	1314	1397	—	—	—	—	—	—
23·17	5·	1·2109	15	—	18	·0204	990	1052	—	—	—	—	—	—
39·83	10·	1·4091	15	—	18	·0273	423	450	—	—	—	—	—	—
·0055	·000975	—	—	228·8[2]	25	—	—	2141	—	—	—	—	—	—
·0109	·00195	—	—	231·2	25	—	—	2164	—	—	—	—	—	—
·0219	·00390	—	—	233·1	25	—	—	2181	—	—	—	—	—	—
·0438	·0078	—	—	232·6	25	—	—	2177	—	—	—	—	—	—
·0875	·0156	—	—	230·7	25	—	—	2158	—	—	—	—	—	—
·175	·0312	—	—	228·9	25	—	—	2142	—	—	—	—	—	—
·350	·0625	1·0026	15	225·3	25	—	—	2108	—	—	—	—	—	—
·697	·125	1·0061	15	220·2	25	—	—	2063	—	—	—	—	—	—
1·386	·25	1·0121	15	214·6	25	—	—	2008	—	—	—	—	—	—
2·743	·5	1·0230	15	206·4	25	—	—	1932	—	—	—	—	—	—
·238	·0424	—	—	82·5[3]	18	—	1946	2069	—	—	—	—	—	—
·457	·0816	—	—	158	18	—	1938	2060	—	—	—	—	—	—
·575	·103	1·0049	15	210	18	—	2039	2162	—	—	—	—	—	—
·857	·1537	1·0077	15	292	18	—	1900	2020	—	—	—	—	—	—
1·146	·206	1·0101	15	408	18	—	1980	2105	—	—	—	—	—	—
2·272	·412	1·0191	15	786	18	—	1908	2028	—	—	—	—	—	—
4·467	·825	1·0367	15	1470	18	—	1782	1894	—	—	—	—	—	—

Sodic Hydrate.
Equivalent Gramme Molecule, NaOH, 40·04.

1·954	·5	1·0225	15	817[1]	18	·0194	1634	1737	—	—	—	—	—	—
3·828	1·	1·0441	15	1488	18	·0199	1488	1581	—	—	—	—	—	—
7·366	2·	1·0850	15	2447	18	·0209	1223	1300	—	—	—	—	—	—
10·68	3·	1·1224	15	3020	18	·0221	1007	1070	—	—	—	—	—	—
13·81	4·	1·1569	15	3264	18	·0241	816	867	—	—	—	—	—	—
16·79	5·	1·1896	15	3259	18	·0266	652	693	—	—	—	—	—	—
30·	10·	1·3320	15	1896	18	·0452	190	202	—	—	—	—	—	—
·00385	·000975	—	—	211·6[2]	25	—	—	1980	—	—	—	—	—	—
·0077	·00195	—	—	215·1	25	—	—	2013	—	—	—	—	—	—
·0155	·0039	—	—	216·7	25	—	—	2028	—	—	—	—	—	—
·0311	·0078	—	—	215·2	25	—	—	2011	—	—	—	—	—	—
·0622	·0156	—	—	212·4	25	—	—	1988	—	—	—	—	—	—
·124	·0312	—	—	210·7	25	—	—	1972	—	—	—	—	—	—
·248	·0625	1·0023	15	205·0	25	—	—	1918	—	—	—	—	—	—

[1] Kohlrausch, *Wied. Annal.* vol. vi. p. 150.

[2] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 355.

SODIC HYDRATE—*continued*.

Equivalent Gramme Molecule, NaOH, 40·04.

			°		°					°			°	
—	·108	—	—	—	—	—	—	—	·843[4]	—	—	—	—	—
·495	·125	1·0055	15	199·3	25	—	—	1865	—	—	—	—	—	—
·986	·25	1·0120	15	191·0	25	—	—	1787	—	—	—	—	—	—
—	·285	—	—	—	—	—	—	—	·800	—	—	—	—	—
1·954	·5	1·0225	15	181·6	25	—	—	1691	—	—	—	—	—	—
—	1·084	—	—	—	—	—	—	—	·827	—	—	—	—	—
·127	·0319	—	15	56·7[3]	18	—	1777	1889	—	—	—	—	—	—
·240	·0602	1·0022	15	106	18	—	1760	1871	—	—	—	—	—	—
·501	·1257	1·0056	15	217	18	—	1722	1830	—	—	—	—	—	—
·642	·1618	1·0074	15	287	18	—	1771	1883	—	—	—	—	—	—
1·012	·2564	1·0121	15	424	18	—	1515	1610	—	—	—	—	—	—
1·274	·3237	1·0150	15	548	18	—	1691	1797	—	—	—	—	—	—
2·515	·6474	1·0286	15	1022	18	—	1579	1678	—	—	—	—	—	—
4·893	1·2947	1·0576	15	1805	18	—	1394	1481	—	—	—	—	—	—

[3] Lenz, *Mémoire de l'Acad. de St. Pétersbourg*, vol. xxvi.

[4] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

LITHIUM HYDRATE.

Equivalent Gramme Molecule, LiOH, 24·02.

·0023	·000976	—	—	204·4[1]	25	—	—	1913	—	—	—	—	—	—
·0047	·00195	—	—	206·3	25	—	—	1931	—	—	—	—	—	—
·0094	·0039	—	—	206·8	25	—	—	1935	—	—	—	—	—	—
·0188	·0078	—	—	205·9	25	—	—	1927	—	—	—	—	—	—
·0375	·0156	—	—	202·2	25	—	—	1892	—	—	—	—	—	—
·075	·0312	—	—	199·6	25	·0194	—	1868	—	—	—	—	—	—
·150	·0625	—	—	193·8	25	—	—	1814	—	—	—	—	—	—
·300	·125	—	—	186·5	25	—	—	1745	—	—	—	—	—	—
—	·25	—	—	179·2	25	—	—	1677	—	—	—	—	—	—
—	·201	—	—	—	—	—	—	—	·857[3]	—	—	—	—	—
—	·402	—	—	—	—	—	—	—	·863	—	—	—	—	—
—	·5	—	—	694[2]	18	·0191	1388	1475	—	—	—	—	—	—
—	1·	—	—	1253	18	·0196	1253	1332	—	—	—	—	—	—
—	1·495	—	—	—	—	—	—	—	·890	—	—	—	—	—
—	2·	—	—	2108	18	·0202	1054	1120	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 356.

[2] Kohlrausch, *Wied. Annal.* vol. vi. p. 151.

[3] Kuschel, *Wied. Annal.* vol. xiii. p. 289.

Barium Hydrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Ba(OH)_2$, 85·5.

·0083	·000976	—	—	218·4 [1]	25	—	—	2322 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 357.
·0166	·00195	—	—	219·8	25	—	—	2336	—	—	—	—	—	—	
·0332	·0039	—	—	218·7	25	—	—	2325	—	—	—	—	—	—	
·0665	·0078	—	—	215·9	25	—	—	2295	—	—	—	—	—	—	
·133	·0156	—	—	210·3	25	—	—	2235	—	—	—	—	—	—	[2] At 25°.
·266	·0312	—	—	201·0	25	—	—	2137	—	—	—	—	—	—	
·532	·0625	—	—	192·3	25	—	—	2044	—	—	—	—	—	—	
—	·125	—	—	183·9	25	—	—	1955	—	—	—	—	—	—	
—	·25	—	—	174·4	25	—	—	1854	—	—	—	—	—	—	

Strontium Hydrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Sr(OH)_2$, 60·75.

·0059	·000976	—	—	209·2 [1]	25	—	—	2224 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 357.
·0118	·00195	—	—	212·2	25	—	—	2256	—	—	—	—	—	—	
·0236	·0039	—	—	211·7	25	—	—	2250	—	—	—	—	—	—	
·0472	·0078	—	—	209·0	25	—	—	2222	—	—	—	—	—	—	
·0945	·0156	—	—	202·5	25	—	—	2152	—	—	—	—	—	—	[2] At 25°
·189	·0312	—	—	196·5	25	—	—	2089	—	—	—	—	—	—	
·378	·0625	—	—	190·1	25	—	—	2021	—	—	—	—	—	—	

Calcium Hydrate.

Equivalent Gramme Molecule, $\frac{1}{2}$ $Ca(OH)_2$, 37.

·0036	·000976	—	—	213·2 [1]	25	—	—	2266 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 357.
·0072	·00195	—	—	215·4	25	—	—	2290	—	—	—	—	—	—	
·0144	·0039	—	—	213·4	25	—	—	2268	—	—	—	—	—	—	
·0288	·0078	—	—	209·3	25	—	—	2225	—	—	—	—	—	—	
·0575	·0156	—	—	200·2	25	—	—	2128	—	—	—	—	—	—	[2] At 25°.
·115	·0312	—	—	190·5	25	—	—	2025	—	—	—	—	—	—	

Ammonia.

Equivalent Gramme Molecule, NH_3, 17·04.

·000017	·00001	—	—	—	18	—	560 [1]	595	—	—	—	—	—	—	[1] Kohlrausch, *Wied. Annal.* vol. xxvi. p. 197.
·000034	·00002	—	—	—	18	—	700	744	—	—	—	—	—	—	
·000102	·00006	—	—	—	18	—	690	733	—	—	—	—	—	—	

AMMONIA—*continued*.

Equivalent Gramme Molecule, NH_3, 17·04.

			°		°					°			°	
·00017	·0001	—	—	—	18	—	610	648	—	—	—	—	—	—
·00034	·0002	—	—	—	18	—	500	531	—	—	—	—	—	—
·00102	·0006	—	—	—	18	—	330	351	—	—	—	—	—	—
·0017	·001	—	—	—	18	—	260	276	—	—	—	—	—	—
·0034	·002	—	—	—	18	—	190	202	—	—	—	—	—	—
·0102	·006	—	—	—	18	—	116	123	—	—	—	—	—	—
·017	·01	—	—	—	18	—	92	98	—	—	—	—	—	—
·051	·03	—	—	—	18	—	50	53	—	—	—	—	—	—
·085	·05	—	—	—	18	—	43	46	—	—	—	—	—	—
·17	·1	—	—	—	18	—	31	33	—	—	—	—	—	—
·85	·5	—	—	—	18	—	12	12·7	—	—	—	—	—	—
1·71	1·	·9928	16	—	18	—	8·4	8·9	—	—	—	—	—	—
5·22	3·	·9776	16	—	18	—	3·3	3·5	—	—	—	—	—	—
—	5·	—	—	—	18	—	2·4	2·5	—	—	—	—	—	—
—	10·	—	—	—	18	—	·5	·53	—	—	—	—	—	—
·00165	·000975	—	—	37·0 [2]	25	—	—	393 [3]	—	—	—	—	—	—
·0033	·00195	—	—	25·8	25	—	—	274	—	—	—	—	—	—
·0066	·0039	—	—	17·9	25	—	—	189	—	—	—	—	—	—
·0132	·0078	—	—	12·4	25	—	—	132	—	—	—	—	—	—
·0265	·0156	—	—	8·7	25	—	—	92	—	—	—	—	—	—
·053	·0312	—	—	6·13	25	—	—	65	—	—	—	—	—	—
·106	·0625	—	—	4·27	25	—	—	45	—	—	—	—	—	—
·212	·125	—	—	3·01	25	—	—	32	—	—	—	—	—	—
·425	·25	—	—	2·10	25	—	—	22	—	—	—	—	—	—
·85	·5	—	—	1·46	25	—	—	15·5	—	—	—	—	—	—

[2] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 358.

[3] At 25°.

METHYLAMINE.

Equivalent Gramme Molecule, CH_3NH_2, 31·04.

·00305	·000976	—	—	108·0 [1]	25	—	—	1148 [2]	—	—	—	—	—	—
·0061	·00195	—	—	84·7	25	—	—	900	—	—	—	—	—	—
·0122	·0039	—	—	64·8	25	—	—	689	—	—	—	—	—	—
·0245	·0078	—	—	49·0	25	—	—	521	—	—	—	—	—	—
·049	·0156	—	—	36·2	25	—	—	385	—	—	—	—	—	—

[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 360.

[2] At 25°.

·098	·0312	—	—	26·4	25	—	—	281	—	—	—	—	—	—	
·195	·0625	—	—	19·1	25	—	—	204	—	—	—	—	—	—	
·39	·125	—	—	13·5	25	—	—	144	—	—	—	—	—	—	
·78	·25	—	—	9·5	25	—	—	101	—	—	—	—	—	—	
—	·5	—	—	6·4	25	—	—	68	—	—	—	—	—	—	

ETHYLAMINE.

Equivalent Gramme Molecule, $C_2H_5NH_2$, 45·04.

·0044	·000976	—	—	112·0 [1]	25	—	—	1190 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 360.
·0088	·00195	—	—	88·0	25	—	—	936	—	—	—	—	—	—	
·0175	·0039	—	—	66·9	25	—	—	711	—	—	—	—	—	—	
·035	·0078	—	—	50·2	25	—	—	533	—	—	—	—	—	—	
·070	·0156	—	—	36·9	25	—	—	393	—	—	—	—	—	—	[2] At 25°.
·140	·0312	—	—	26·8	25	—	—	285	—	—	—	—	—	—	
·281	·0625	—	—	19·3	25	—	—	205	—	—	—	—	—	—	
·562	·125	—	—	13·5	25	—	—	144	—	—	—	—	—	—	
—	·25	—	—	9·3	25	—	—	99	—	—	—	—	—	—	
—	·5	—	—	6·1	25	—	—	64	—	—	—	—	—	—	

PROPYLAMINE.

Equivalent Gramme Molecule, $C_3H_7NH_2$, 59·04.

·0042	·000976	—	—	97·7 [1]	25	—	—	1038 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 361.
·0084	·00195	—	—	77·2	25	—	—	821	—	—	—	—	—	—	
·0169	·0039	—	—	59·2	25	—	—	629	—	—	—	—	—	—	
·0338	·0078	—	—	44·3	25	—	—	471	—	—	—	—	—	—	
·0675	·0156	—	—	32·6	25	—	—	347	—	—	—	—	—	—	[2] At 25°.
·135	·0312	—	—	23·7	25	—	—	252	—	—	—	—	—	—	
·37	·0625	—	—	16·9	25	—	—	180	—	—	—	—	—	—	
·74	·125	—	—	11·9	25	—	—	127	—	—	—	—	—	—	
—	·25	—	—	8·1	25	—	—	86	—	—	—	—	—	—	

ISOBUTYLAMINE.

Equivalent Gramme Molecule, $C_4H_9NH_2$, 73·04.

·0071	·000976	—	—	82·3 [1]	25	—	—	875 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii.
·0142	·00195	—	—	64·5	25	—	—	686	—	—	—	—	—	—	
·0285	·0039	—	—	49·2	25	—	—	523	—	—	—	—	—	—	p. 361.
·057	·0078	—	—	36·6	25	—	—	389	—	—	—	—	—	—	[2] At 25°.

Isobutylamine—*continued*.

Equivalent Gramme Molecule, $C_4H_9NH_2$, 73·04.

			°		°					°			°	
·114	·0156	—	—	26·9	25	—	—	286	—	—	—	—	—	—
·228	·0312	—	—	19·4	25	—	—	207	—	—	—	—	—	—
·455	·0625	—	—	13·8	25	—	—	147	—	—	—	—	—	—
·91	·125	—	—	9·6	25	—	—	103	—	—	—	—	—	—
—	·25	—	—	6·4	25	—	—	69	—	—	—	—	—	—

Amylamine.

Equivalent Gramme Molecule, $C_5H_{11}NH_2$, 87·04.

·0085	·000976	—	—	97·5 [1]	25	—	—	1036 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii p. 362.
·017	·00195	—	—	77·4	25	—	—	823	—	—	—	—	—	—	[2] At 25°.
·034	·0039	—	—	59·9	25	—	—	637	—	—	—	—	—	—	
·068	·0078	—	—	44·4	25	—	—	472	—	—	—	—	—	—	
·136	·0156	—	—	33·2	25	—	—	354	—	—	—	—	—	—	
·272	·0312	—	—	24·2	25	—	—	257	—	—	—	—	—	—	
·544	·0625	—	—	17·2	25	—	—	183	—	—	—	—	—	—	
—	·125	—	—	11·9	25	—	—	127	—	—	—	—	—	—	
—	·25	—	—	7·9	25	—	—	84	—	—	—	—	—	—	

Dimethylamine.

Equivalent Gramme Molecule, $(CH_3)_2NH$, 45·04.

·0044	·000976	—	—	120·7 [1]	25	—	—	1283 [2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 363.
·0088	·00195	—	—	95·7	25	—	—	1017	—	—	—	—	—	—	[2] At 25°.
·0175	·0039	—	—	73·9	25	—	—	786	—	—	—	—	—	—	
·035	·0078	—	—	55·9	25	—	—	595	—	—	—	—	—	—	
·070	·0156	—	—	41·6	25	—	—	442	—	—	—	—	—	—	
·140	·0312	—	—	30·4	25	—	—	323	—	—	—	—	—	—	
·281	·0625	—	—	21·8	25	—	—	232	—	—	—	—	—	—	
·562	·125	—	—	15·4	25	—	—	164	—	—	—	—	—	—	
—	·25	—	—	10·6	25	—	—	113	—	—	—	—	—	—	
—	·5	—	—	6·9	25	—	—	73	—	—	—	—	—	—	

Diethylamine.

Equivalent Gramme Molecule, $(C_2H_5)_2NH$, 73·04.

·0071	·000976	—	—	130·3[1]	25	—	—	1382[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 363.
·0142	·00195	—	—	108·4	25	—	—	1152	—	—	—	—	—	—	
·0285	·0039	—	—	85·9	25	—	—	913	—	—	—	—	—	—	
·057	·0078	—	—	65·8	25	—	—	699	—	—	—	—	—	—	[2] At 25°.
·114	·0156	—	—	49·4	25	—	—	525	—	—	—	—	—	—	
·228	·0312	—	—	36·1	25	—	—	384	—	—	—	—	—	—	
·455	·0625	—	—	26·0	25	—	—	277	—	—	—	—	—	—	
·910	·125	—	—	18·2	25	—	—	193	—	—	—	—	—	—	
—	·25	—	—	12·3	25	—	—	131	—	—	—	—	—	—	

Trimethylamine.

Equivalent Gramme Molecule, $(CH_3)_3N$, 59·04.

·0058	·000976	—	—	56·8[1]	25	—	—	604[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 364.
·0116	·00195	—	—	42·8	25	—	—	455	—	—	—	—	—	—	
·0231	·0039	—	—	32·2	25	—	—	342	—	—	—	—	—	—	
·0462	·0078	—	—	23·7	25	—	—	252	—	—	—	—	—	—	[2] At 25°.
·0925	·0156	—	—	17·3	25	—	—	183	—	—	—	—	—	—	
·185	·0312	—	—	12·5	25	—	—	132	—	—	—	—	—	—	
·370	·0625	—	—	8·9	25	—	—	94	—	—	—	—	—	—	
·740	·125	—	—	6·2	25	—	—	66	—	—	—	—	—	—	
—	·25	—	—	4·2	25	—	—	44	—	—	—	—	—	—	
—	·5	—	—	2·63	25	—	—	28	—	—	—	—	—	—	

Triethylamine.

Equivalent Gramme Molecule, $(C_2H_5)_3N$, 101·04.

·0099	·000976	—	—	111·6[1]	25	—	—	1186[2]	—	—	—	—	—	—	[1] Ostwald, *Jour. für Chemie*, vol. xxxiii. p. 364.
·0198	·00195	—	—	87·6	25	—	—	931	—	—	—	—	—	—	
·0395	·0039	—	—	66·6	25	—	—	708	—	—	—	—	—	—	
·079	·0078	—	—	49·7	25	—	—	528	—	—	—	—	—	—	[2] At 25°.
·158	·0156	—	—	36·4	25	—	—	387	—	—	—	—	—	—	
·315	·0312	—	—	26·1	25	—	—	277	—	—	—	—	—	—	
·630	·0625	—	—	18·5	25	—	—	196	—	—	—	—	—	—	
—	·125	—	—	12·6	25	—	—	134	—	—	—	—	—	—	
—	·25	—	—	8·2	25	—	—	88	—	—	—	—	—	—	
—	·5	—	—	4·8	25	—	—	51	—	—	—	—	—	—	

Investigation of the Earthquake and Volcanic Phenomena of Japan. Thirteenth Report of the Committee, consisting of the Rt. Hon. Lord KELVIN, Professor W. G. ADAMS, Mr. J. T. BOTTOMLEY, Professor A. H. GREEN, Professor C. G. KNOTT, *and* Professor JOHN MILNE (*Secretary*). (*Drawn up by the Secretary.*)

THE GRAY-MILNE SEISMOGRAPH.

THE first of the above seismographs, constructed in 1883, partly at the expense of the British Association, still continues to be used as the standard instrument at the Central Observatory in Tokio.

I am indebted to Mr. K. Kobayashi, the Director of the Observatory, for the following table of its records :—

Catalogue of Earthquakes recorded at the Central Meteorological Observatory in Tokio between May 1892 *and April* 1893.

No.	Month	Date	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
					1892.					
			H. M. S.	M. S.						
1,241	V.	3	1 18 53 A.M.	1 3	E.–W.	0·9	0·2	—	—	slow
1,242	„	5	3 10 49 P.M.	—	—	feeble		—	—	—
1,243	„	11	6 48 51 A.M.	0 45	W.N.W.–E.S.E.	0·1	0·2	slight		quick
1,244	„	12	2 36 54 P.M.	—	slight	—	—	—	—	—
1,245	„	18	7 41 1 P.M.	—	—	very slight		—	—	—
1,246	„	20	7 17 42 A.M.	—	—	very slight		—	—	—
1,247	„	24	9 1 10 P.M.	—	—	very slight		—	—	—
1,248	VI.	3	4 23 46 A.M.	—	—	slight		—	—	—
1,249	„	„	7 9 57 A.M.	7 30	E.S.E.–W.N.W.	2·0	28·4	0·8	4·4	very quick
1,250	„	3	1 35 0 P.M.	—	—	slight		—	—	—
1,251	„	5	1 10 3 P.M.	—	—	very slight		—	—	—
1,252	„	8	9 3 12 A.M.	—	—	slight		—	—	—
1,253	„	10	2 52 44 A.M.	—	—	slight		—	—	—
1,254	„	15	0 45 33 P.M.	—	—	slight		—	—	—
1,255	„	19	7 37 0 P.M.	—	—	slight		—	—	—
1,256	„	28	11 29 36 P.M.	—	—	slight		—	—	—
1,257	„	30	6 13 20 P.M.	—	—	slight		—	—	—
1,258	VII.	3	1 9 26 A.M.	—	—	very slight		—	—	—
1,259	„	„	7 20 56 P.M.	—	—	slight		—	—	—
1,260	„	6	2 58 16 A.M.	1 30	E.–W.	slight		—	—	slow
1,261	„	20	3 10 6 A.M.	1 30	N.N.W.–S.S.E.	0·9	0·4	—	—	„
1,262	„	„	6 11 10 A.M.	3 20	N.N.W.–S.S.E.	0·8	0·7	—	—	„
1,263	„	„	8 29 41 A.M.	—	—	very slight		—	—	—
1,264	„	„	11 31 44 A.M.	1 0	S.–N.	slight		—	—	slow
1,265	„	„	2 9 52 P.M.	2 30	S.–N.	slight		—	—	very slow
1,266	„	21	0 56 46 A.M.	—	—	very slight		—	—	—
1,267	„	23	9 19 39 P.M.	—	—	slight		—	—	—
1,268	„	24	0 11 21 A.M.	—	—	slight		—	—	—
1,269	„	26	9 22 25 A.M.	—	—	very slight		—	—	—
1,270	„	27	10 20 42 A.M.	1 30	N.N.W.–S.S.E.	0·8	0·8	very	slight	slow
1,271	„	29	7 0 3 P.M.	—	—	slight		—	—	—
1,272	VIII.	20	2 29 29 A.M.	—	—	slight		—	—	—
1,273	„	28	10 19 1 P.M.	1 30	E.–W.	slight		—	—	slow
1,274	IX.	4	10 7 43 A.M.	—	—	very slight		—	—	—
1,275	„	7	5 41 57 A.M.	3 20	S.E.–N.W.	1·7	1·1	—	—	slow

CATALOGUE OF EARTHQUAKES—*continued.*

No.	Month	Date	Time	Duration	Direction	Maximum Period and Amplitude of Horizontal Motion		Maximum Period and Amplitude of Vertical Motion		Nature of Shock
						secs.	mm.	secs.	mm.	
			H. M. S.	M. S.						
1,276	IX.	11	9 31 47 P.M.	—	—	very slight		—	—	—
1,277	„	13	11 29 42 P.M.	2 0	E.S.E.-W.N.W.	0·4	2·6	0·3	0·3	quick
1,278	„	15	2 57 28 P.M.	—	—	very slight		—	—	—
1,279	„	17	11 51 40 A.M.	—	—	very slight		—	—	—
1,280	„	18	1 34 17 A.M.	—	—	very slight		—	—	—
1,281	X.	1	2 6 31 A.M.	—	—	very slight		—	—	—
1,282	„	„	9 21 36 A.M.	—	—	very slight		—	—	—
1,283	„	6	0 50 32 A.M.	—	—	very slight		—	—	—
1,284	„	7	0 23 37 A.M.	—	—	very slight		—	—	—
1,285	„	8	1 35 54 P.M.	0 20	E.-W.	0·3	0·2	—	—	quick
1,286	„	14	7 54 46 P.M.	—	—	very slight		—	—	—
1,287	„	19	0 53 9 P.M.	—	—	very slight		—	—	—
1,288	„	21	7 28 26 P.M.	—	—	slight		—	—	—
1,289	„	22	7 9 54 P.M.	—	—	slight		—	—	—
1,290	„	25	10 11 38 P.M.	—	—	slight		—	—	—
1,291	„	27	3 1 4 P.M.	—	—	slight		—	—	—
1,292	XI.	5	1 48 53 A.M.	0 40	E.-W.	1·2	0·4	—	—	slow
1,293	„	15	11 6 2 P.M.	—	—	feeble		—	—	—
1,294	„	16	4 25 44 P.M.	—	—	feeble		—	—	—
1,295	„	21	10 37 53 P.M.	2 30	S.E.-N.W.	0·3	0·7	0·2	0·2	quick
1,296	XII.	6	3 30 22 A.M.	—	—	slight		—	—	—
1,297	„	„	4 22 38 P.M.	1 30	N.-S.	1·0	0·6	—	—	slow
1,298	„	„	7 1 9 P.M.	1 30	S.-N.	slight		—	—	„
1,299	„	9	8 1 1 A.M.	1 30	S.E.-N.W.	0·4	0·8	slight		quick
1,300	„	„	10 43 57 A.M.	2 40	E.S.E.-W.N.W.	1·5	1·5	—	—	slow
1,301	„	10	10 0 46 A.M.	—	—	slight		—	—	—
1,302	„	11	1 34 39 A.M.	2 30	W.S.W.-E.N.E.	1·1	1·1	—	—	slow
1,303	„	12	2 56 57 P.M.	—	—	very slight		—	—	—
1,304	„	24	2 12 31 P.M.	—	—	slight		—	—	—
					1893.					
1,305	I.	3	0 35 25 P.M.	1 30	N.W.-S.E.	0·5	0·6	0·4	0·2	quick
1,306	„	8	5 40 27 P.M.	2 30	W.N.W.-E.S.E.	0·3	3·5	0·3	0·9	„
1,307	„	16	10 37 18 P.M.	—	—	very slight		—	—	—
1,308	„	20	8 10 21 A.M.	—	—	slight		—	—	—
1,309	„	23	1 7 52 P.M.	—	—	slight		—	—	—
1,310	II.	11	6 46 31 A.M.	1 0	E.-W.	slight		—	—	quick
1,311	„	17	7 13 59 A.M.	0 50	E.-W.	0·3	0·6	slight		„
1,312	„	19	1 39 52 A.M.	—	—	very slight		—	—	—
1,313	„	21	2 48 3 A.M.	—	—	very slight		—	—	—
1,314	III.	6	8 52 18 A.M.	3 20	E.S.E.-W.N.W.	0·6	1·7	0·3	0·2	quick
1,315	„	17	9 6 31 A.M.	1 0	E.-W.	0·2	0·3	slight		„
1,316	„	24	5 4 52 A.M.	3 30	N.E.-S.W.	1·3	0·6	—	—	slow
1,317	„	26	7 47 21 P.M.	—	—	very slight		—	—	—
1,318	„	„	8 27 52 P.M.	—	—	very slight		—	—	—
1,319	IV.	4	7 33 11 A.M.	—	E.-W.	slight		—	—	—
1,320	„	5	1 8 46 P.M.	1 0	E.-W.	slight		—	—	quick
1,321	„	9	8 21 6 P.M.	—	E.-W.	slight		—	—	—
1,322	„	19	11 22 25 P.M.	—	—	slight		—	—	—

ON THE MOVEMENTS OF HORIZONTAL PENDULUMS.

In a report to this Association in 1881 reference was made to the observation of earth-tremors which it was thought might be connected with the occurrence of earthquakes. The analysis of records obtained during succeeding years showed that the surmise was without foundation. In 1883 an account was given of experiments with various forms of tromometers and delicate levels. The Report for 1884 contained further notes on the observations of earth-pulsations and earth-tilting. In 1885

an instrument was described which gave a continuous record of tremors and deflections of the vertical, and reference was made to earth-waves which had a period of from fifteen to sixty minutes. The Reports for 1887 and 1888 formulated certain laws respecting the occurrence of earth tremors or pulsations. Full accounts of all this work have been published in the 'Transactions of the Seismological Society.' Last year I described to this Association a method for the investigation of earth-pulsations and earth-tilting, which consisted in making a continuous photographic record of the spots of light reflected from mirrors carried by two horizontal pendulums. These pendulums, which swing in planes at right angles to each other, are each made from a piece of aluminium wire, 60 mm. in length, tipped with a needle point resting in an agate cup. This is held in a horizontal position by means of a quartz fibre. When adjusted so that the period of swing is from five to six seconds, I find that a deflection of the spot of light upon the recording film of 1 mm. with one instrument corresponds to a tilting of 0·54″, and with the other instrument of 0·68″. The distance of the lamp and film from the mirrors, which are arranged to swing one above the other, is 3 feet.

When describing this instrument in 1892 I referred to it as being new. In this I was mistaken, as similar arrangements have been used in Potsdam and other places by Dr. E. von Rebeur-Paschwitz (see 'Der. Ksl. Leop.-Carol. Deutschen Akademie der Naturforscher,' Band LX. No. 1). In Japan the primary object of the observations was to obtain continuous records of earth-waves (*tremors*), with the result that with these records the records of other phenomena like those of earth-tilting were found. In Potsdam the cycle of observations was reversed, the primary object being to record small changes in the vertical, with the unavoidable result that distant earthquakes, tremors, and other phenomena were also recorded.

The pendulums I have used have been exceedingly light, and intended to follow the movements impressed upon them by a succession of earth-waves.

The pendulums of Dr. von Rebeur-Paschwitz were comparatively heavy, and were adjusted to move with periods of from twelve to eighteen seconds.

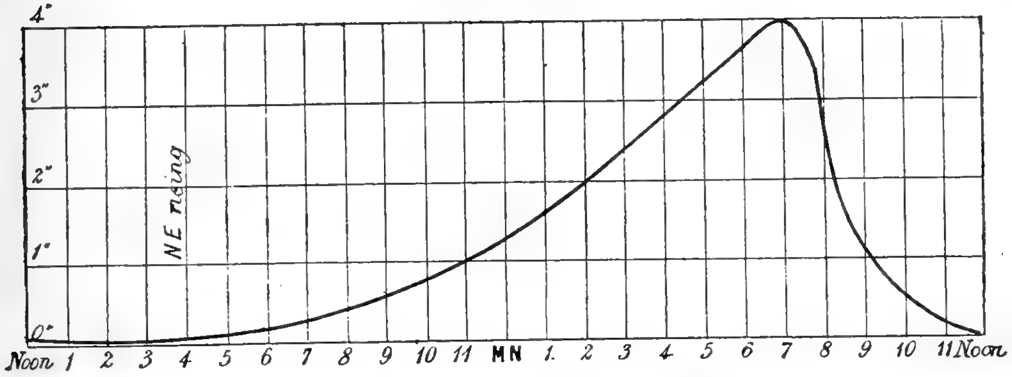
The results obtained in December and January last are described in detail in the 'Seismological Journal,' whilst that which has been done between February and April is briefly as follows:—

Daily Tilting.

Almost every day the records show that the spots of light have been displaced in a direction which would correspond with a displacement should the N.E. or N.N.E. side of the column on which the pendulums stand be gently raised, and then gently but rather more quickly lowered. Occasionally the tilting is from the north, the pendulum in the meridian which records the east and west motion remaining stationary.

The movement commences about 7 P.M., and continues steadily up to about 7 or 8 A.M. From this to about 10 A.M. there is a quick return to the normal position, where it remains until evening. The amount of tilting which would produce these deflections is from 2″ to 10″. The average, as shown in the diagram, is about 4″.

FIG. 1.—Average daily N.E.–S.W. tilting of a stone column in Tokio, February and March 1893.



The following table is a comparison of the movements observed by Dr. von Rebeur-Paschwitz and those observed in Tokio :—

Movements of Pendulums	Wilhelmshaven	Potsdam	Teneriffe	Tokio
Completion of Easterly movement (E. sunk)	2 P.M.	3.30 P.M.	3 to 4 P.M.	7 P.M.
Completion of Westerly movement (E. risen)	4 or 5 A.M.	8 A.M.	9 A.M.	8 A.M.
Amplitude of motion . . .	1″·44 to 4″·32	0″·14 to 1″·13	0″·95 to 0″·04	4″ to 10″

Effects of Changes in Temperature.

The tests which have been applied to determine the effects produced by a change in temperature have been severe. After closing all doors a stove which stands about 3 feet distant from the S.W. corner of the column has been lighted, and the temperature raised, for example, from 49° F. to 85° F. This took three hours, and during this time the corner of the column became sensibly warm to the hand. All was then allowed to cool. The effect as shown upon the photographic trace and partly by other instruments upon the column was that about half-an-hour after lighting the fire the N.E. side of the column very quickly sank, indicating a tilting from S.W. to N.E. of 2″. After this it sank until an amplitude of 6″ was reached. Here it remained for several hours, and then gradually rose. This, it will be observed, is a result that can be obtained by a change of temperature of 36° F.

Undoubtedly temperature effects exist in the records I have taken ; but as it has often happened that the change in temperature during twenty-four hours inside my observatory has not been more than 4° F., while the daily movements have exceeded that which I obtain by a change of 36° F., I cannot attribute the movements I observe to fluctuations in atmospheric temperature in the vicinity of the column.

To determine how far slow and regular changes in temperature may modify the diagrams will be a subject for future investigation.

Barometrical Effects.

On the soft, marshy ground near Wilhelmshaven, Dr. von Rebeur-Paschwitz observes that a change in the vertical of $\frac{1}{4}''$ corresponds to a change of 1 mm. in barometrical pressure; in fact, the district behaves as if it were the vacuum chamber of an aneroid. In Tokio the effects are not so pronounced, yet in many instances a N.N.E. tilting has corresponded with a rise in the barometer. On two or three days when the barometrical changes have been small the daily movements have been small, but there are other instances where the daily movement has continued and the barometer has been steady. In the smaller movements, and in the few cases where the direction of one component of the daily movement has been reversed, there does not appear to be any connection with the barometer.

Mr. T. Wada, of the Meteorological Observatory, tells me that the daily maximum and minimum barometrical changes vary with the season, the yearly average being as follows:—

—	Minimum	Maximum	Minimum	Maximum
	H. M.	H. M.	H. M.	H. M.
For North Japan . .	3 8 A.M.	*9 0* A.M.	*2 5* P.M.	9 9 P.M.
For South Japan . .	3 7 A.M.	*9 2* A.M.	*3 2* P.M.	10 1 P.M.

Those which are italicised are the most pronounced. In winter there are two other periods, viz.:—

—	Minimum	Maximum
	H. M.	H. M.
For North Japan	0 5 A.M.	2 3 A.M.
For South Japan	0 5 A.M.	1 7 A.M.

I have not observed any change accompanying these periods.

Possible Relationship with Magnetic Movements.

The relationship between the movements of the pendulums and the daily changes in magnetic declination suggests the idea that the phenomena which are being observed are not altogether unconnected with magnetic influences.

In Tokio the declination is farthest west about 2 P.M., and farthest east at 8 A.M.; that is to say, when the magnetic needle is farthest east the north end of a north south boom of my instrument is farthest west. That the movements of the horizontal pendulums and those of a magnetic needle take place at the same time but in opposite directions has also been observed by Dr. von Rebeur-Paschwitz in Potsdam and Wilhelmshaven. In my instrument the pivot, which is a steel needle point 8 mm. in length, is pivoted at its southern end.

Geological Structure and Direction of Movements.

A very significant fact, possibly connecting the observed movements with geological structure, is that the N.E. or N.N.E. direction of tilting

is at right angles to a well-defined axis of rock crumpling, which shows itself in the N.W. to S.E. strike of the mountains some thirty miles distant, and which line of folding probably continues beneath the plain of Tokio.

Another point not to be overlooked is that the direction of earthquake motion across the Tokio plain is in the majority of cases also at right angles to the direction of mountain strike. During the next summer I shall endeavour to instal horizontal pendulums on the rocks themselves, one of them parallel to the dip and the other at right angles to this direction.

Irregular Movements.

It often happens that superimposed upon the daily wave there are sinuosities with amplitudes of 1″ or 2″. These appear to be chiefly marked on the east and west components of the diagrams. They have periods of from three to six hours, and generally occur as a sinking during the early morning or between midnight and 8 or 9 A.M., at which time the east is usually rising.

On February 17, March 24 and 26, small earthquakes occurred with these sinkings, after which the normal rise was continued. Other earthquakes, which, however, were too small to be measured by ordinary seismographs, were not accompanied by such changes. Before the earthquake of March 6, which probably was of local origin, the spots of light had moved off the scale as if by an abnormally large sinking on the N.E. side. This was at 8.45 P.M. on March 5. I therefore do not know what happened immediately before the shaking, which took place at 8.52 A.M. next morning.

Earth-waves or Earth-pulsations.

(Tremors or Microseismic Disturbances.)

On February 17, 18, and 19 there was a large and well-marked storm of tremors. The barometer did not fall to any remarkable extent, the lowest I noted being 29·7 in. While the movements were continuing the east side of the column was depressed about 2″, and the daily wave did not show itself. With other tremor-storms, which were, however, smaller, the daily wave has been unaffected.

Earthquakes.

From the list of earthquakes at the commencement of this report it will be seen that during the months of February and March nine earthquakes were recorded at the Central Observatory in Tokio. Five of these were measurable by seismographs. Seven out of the nine were recorded at the University Laboratory, which is about $1\frac{1}{2}$ mile distant from the central station. Owing to certain of these having occurred when there had been a temporary interruption in the taking of records—as, for example, when changing a film—it is only possible that three of the seven disturbances should have been photographically recorded.

These records are remarkable for their smallness, apparently showing that, although there had been a sensible motion of the ground, the mirrors had either remained practically at rest, or else they had not been moving for a sufficiently long period of time to produce an impression on the film. As the films, which were prepared for me by Professor W. K.

Burton, are particularly sensitive, I am inclined to the opinion that there was less tilting accompanying these earthquakes than there is in the waves which constitute a tremor-storm; in fact, the earthquakes which only produced deflections of 2 mm. were elastic tremors, while so-called tremors which may produce deflections of 25 mm. are earth-waves.

These observations led me to note the effects produced upon a film when the mirrors had been caused to swing by placing my finger upon the iron bed-plate which acts as their support. The result was that either a band about 12 mm. in length was produced or else the trace was blurred, and at the blurr a permanent deflection of about 3 mm. was recorded.

As a result of these experiments I conclude that in all cases where lines are invariably opposite to each other in both components, and are seen as transverse markings in the traces, such lines indicate that the mirrors have been swinging, and the question arises, whether these are due to undulations from distant earthquakes or whether they are due to undulations which, if they were continuous, would constitute a tremor-storm.

If they are tiltings due to distant earthquakes, then on several occasions as many as fourteen of these disturbances have been noted in twenty-four hours. On other days the normal lines are unbroken.

Comparing the photographic traces with the list of 101 earthquakes which were felt in Japan during the month of February, it is seen that only the large ones, like numbers 54 and 61, have been recorded on the film. The traces, however, show that there have been many large disturbances which do not coincide in time with earthquakes noted on the list. It is possible that these may coincide with disturbances which had their origin in other countries, or, what is more likely, with disturbances originating beneath the bed of the Pacific, where, from what we know, seismic activity is at least as great as it is upon the land. An alternative suggestion is that they are the result of movements similar in character to those which constitute a tremor-storm; but whether these are to be attributed to sudden but gentle bendings of rocky strata, or whether their origin is to be sought for amongst causes which are more complex, is for the present a subject about which we are hardly justified in attempting to formulate an hypothesis.

Dr. von Rebeur-Paschwitz in Germany has observed fourteen earthquakes—if all of these really are earthquakes—in eleven months. One of them corresponds in time to the great disturbance of October 28, 1891, when Central Japan was devastated.

Possible Connection between these Observations and other Phenomena.

Assuming that with appliances similar to those used by Dr. von Rebeur-Paschwitz, or to those used in Japan, records of distant earthquakes may be noted, then it would be possible in England, or any other country, not only to note unfelt local disturbances, but also to record, at least, very many of the large disturbances which occur throughout the world.

The importance of such records in determining the velocity with which earth-waves are propagated, or, as was suggested by Lord Kelvin, the determination of elastic constants for the earth's crust, and in solving other problems, is apparent.

Already the observations on earth-tilting seem to have gone sufficiently

far to demand serious attention from practical astronomers. There are many reasons for believing that earth pulsations or undulations have a connection with the escape of fire-damp, and they do not appear to be wholly unconnected with the behaviour of certain physical instruments. For example, as the result of a long series of observations made with an Oertling and a Bunge balance, it seems that there are times when it would be impossible to carry out any delicate weighing operations.

The more important results obtained from the observation of these balances were as follows:—

1. The Oertling, which was a light assay balance, moved more than the Bunge.
2. It was seldom that either of the balances was absolutely at rest.
3. During a day the pointer of the Oertling usually crept through half a division of the ivory scale.
4. Although when caused to swing the period of the Oertling was 41 seconds, it would sometimes be found performing complete swings with periods varying between 17 and 60 seconds. Slower motions might take 50 minutes.
5. It was often observed that both balances would start from rest simultaneously and in the same direction.
6. Periods of disturbance usually occurred with tromometric disturbances, but both balances have often been found moving when tremors were not observable, when the weather was calm and the barometer high, while they have been absolutely at rest during a heavy gale and the barometer at 29·2 inches.
7. The oscillations are not always about the same zero, and the zero for the pointer sometimes changes within a few minutes.

A detailed account of the above observations is given in the 'Seismological Journal,' vol. i.

The Earth-waves of Earthquakes.

From the observations of many who have experienced a large earthquake we may be certain that at such times the surfaces of alluvial plains have been thrown into a series of undulations. During these disturbances, from observations on the behaviour of fluids in vessels, the water in ponds, the irregular and erratic swinging of seismographs, and the character of the resulting records, it is also clear that undulatory, wave-like motions have taken place.

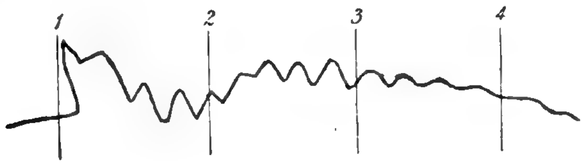
On the occasion of the great earthquake of October 28, 1891, knowing that bracket and conical pendulum seismographs had been tilted, in the Twelfth Report to the Association calculations were given of the maximum slopes of the earth-waves which had caused these movements. Although these calculations may have been interesting on account of their novelty, because any arrangement like a heavy horizontal pendulum when quickly tilted is likely to overswing the point corresponding to that which it would take if the movement had been very slow, serious objections may be raised to the accuracy of the results which were obtained. This consideration led me to devise an angle-measurer in which errors of this description are not likely to occur. It consists of a balance-beam, each arm of which carries a heavy weight so adjusted that the system has but feeble stability. When the stand carrying this is tilted in the plane of the arm, the arm remains horizontal, while a vertical pointer

projecting downwards, as in an ordinary balance, is relatively deflected through an angle corresponding to the tilt. This pointer moves a horizontal lever, at the outer extremity of which a sliding needle writes its record on a smoked-glass plate. Two such pieces of apparatus at right angles to each other, writing on the same surface, constitute a complete instrument.

In one apparatus the balance-arm with its weights is replaced by a heavy metal disc, supported in a vertical plane by knife edges at its centre.

Already one or two earthquakes have been recorded, and as these are the first written records of earth-waves, a portion of one of them is here reproduced:—

FIG. 2.



It shows the E. and W. tilting during a small portion of an earthquake which occurred at 5.40 P.M. on January 8, 1893. The numbers indicate successive seconds, from which we see that the period of the waves varied from $\frac{1}{5}$ to $\frac{1}{4}$ second. The average angular deflection was about 2′ 40″, and the smallest about 1′ 30″.

The movement continued over at least 20 seconds, dying out with hardly perceptible waves having periods of about $\frac{1}{4}$ second. The N. and S. component of tilting was exceedingly small. The direction in which the waves were propagated was approximately E.N.E. to W.S.W.

Inasmuch as tilting apparently occurs whenever we have vertical motion, an unpleasant conclusion—which, however, is not expressed for the first time—is that all the records hitherto published in Japan where vertical motion has been recorded are of but little value. Not only may the horizontal motion have been exaggerated, but the records of vertical motion have also suffered distortion, this being greatest when the arm of the lever seismograph has been parallel to the direction of the wave-slope. The disturbances in which the vertical component has been marked form about 10 per cent. of what should be our most important records.

What we require to know, for example, as an assistance in investigations relating to construction is the configuration, dimensions, and rapidity of recurrence of these earth-waves.

The varying slope of the waves, their period, and their direction of advance, may be measured by the apparatus described.

As an attempt to measure the vertical component of these waves, four lever seismographs have been arranged with their arms at 45° to each other, it being assumed that the record from the instrument with its arm most nearly at right angles to the direction of the advancing wave will be the one which will most closely measure the vertical motion.

Another possible method of measuring this element of earthquake motion would be to avoid errors consequent on tilting by arranging a vertical lever seismograph on gimbals.

Gyroscopes as adjuncts to the solution of these problems have not hitherto proved themselves successful.

On the assumption that the earth-waves in alluvium were harmonic in character and symmetrical in form, in the Report for 1892 it was shown that they might be 20 feet in length; and, knowing their length and period, the velocity of propagation was determined. Even should these waves have lengths several times this amount, some knowledge of their form might be obtained by simultaneously measuring the difference in movement between, say, the heads of a line of stakes at right angles to the direction of the advancing waves and different points of a wire or rod parallel to such a line, but only held in position at its two extremities.

I am led to mention these latter experiments as indications of the important problems which seismologists have yet before them.

List of Earthquakes recorded in Japan in February 1893.

The list of earthquakes appended to this section of the Report is given as an example of a catalogue which might be compiled from the material which since 1885 has been accumulating at the Central Meteorological Observatory in Tokio.

The approximate centre of a disturbance is indicated by its latitude and longitude, while the energy of the disturbance may approximately be deduced from the figures which show in geographical miles the diameter of the area shaken.

Hitherto investigations respecting seismic activity, the periodicity of earthquakes, &c., have been based upon catalogues where only the *number* of shocks have been recorded, and where the disturbances of one seismic area have been inextricably mixed with those from another.

With a catalogue like the one suggested it would be possible to investigate the rate at which seismic activity is decreasing or increasing either in a given area or in Japan as a whole, giving values to the shocks proportional to the area they had shaken. It would assist us in determining whether there is any relationship between the frequency of earthquakes in neighbouring areas. Inasmuch as many earthquakes seem to be the result of sudden fractures or yieldings taking place during the process of rock-crumpling, it does not seem unlikely that the relief of strain along one axis should be altogether without effect upon neighbouring axes where folding may also be in operation. One interesting investigation of the records of a district which has very kindly been made by Mr. F. Ōmori has been to plot the shocks which succeeded the great disturbance of 1891 as a curve, the co-ordinates of which are equal intervals of time and the number of shocks occurring during these intervals.

It will be remembered that the immediate cause of the disturbance was the formation of a large fault which can be traced some forty or fifty miles, together with several minor faults. During the seven months which followed the great shock no less than 3,000 shocks were recorded. How many have been recorded up to date has not been calculated, but from the appended list for the month of February, that is sixteen months after the first shock, sixty-two disturbances were noted.

The curve representing this decrease in activity closely approximates to a rectangular hyperbola, which now, with an average of two shocks per day, is becoming asymptotic.

With the law of decrease deduced from these records Mr. Ōmori

calculates that it will take about thirty years for the district to regain its original stability. The records for the Kumamoto earthquake, which took place in July 1889, show a like result, but with a rate of decrease directly proportional to the intensity of, or the area shaken by, the primary disturbance.

One curious fact connected with the extinction of the Nagoya earthquake is that the district of greatest visible faulting, where valleys were compressed and mountains were lowered, seems to have reached a fair state of quiescence, while the most active settlement, or the district where an extension of faulting is now taking place, is at the S.E. extremity of the main line of original disturbance—a few miles N.E. from Nagoya in Niwa-gun (N. lat. 35° 20′, and E. long. 136° 50′).

Not only would the publication of the catalogue here indicated furnish material very much better than that which has been hitherto attainable for the continuation of investigations like those made by Perrey, Mallet, and other seismologists, but we should have materials for investigations which would be entirely new.

Earthquakes recorded in Japan in February 1893.

No.	Day	Time	Position of centre		Diameter of area shaken in nautical miles	Remarks
			Latitude N.	Longitude E.		
		H. M.				
1	1	2 42 A.M.	35·20	137·0	5	N. of Nagoya.
2	"	6 43 A.M.	35·40	137·0	3	" " "
3	"	2 45 P.M.	35·5	137·0	3	S. " "
4	"	7 21 P.M.	35·30	137·10	3	N.E. of "
5	2	10 3 A.M.	35·30	137·10	3	" Nagoya.
6	"	11 42 P.M.	34·40	132·30	70	S.W. Nipon, Akiken.
7	3	11 30 A.M.	34·50	132·25	3	" " "
8	"	5 20 P.M.	35·20	136·50	20	N. of Nagoya.
9	"	7 23 P.M.	34·50	136·30	3	N. of Ise.
10	"	8 34 P.M.	35·20	137·0	3	N. of Nagoya.
11	"	9 30 P.M.	35·20	137·0	3	" " "
12	"	?	34·0	132·10	3	S.W. Nipon.
13	4	4 55 P.M.	35·20	136·10	3	W. of Gifu.
14	5	10 34 P.M.	36·45	138·0	3	Central Nipon.
15	6	1 15 A.M.	35·0	132·50	3	S.W. Nipon.
16	"	7 55 P.M.	35·0	132·50	3	" "
17	"	9 11 P.M.	36·25	140·0	30	N. of Tokio.
18	"	9 57 P.M.	35·0	132·50	3	S.W. Nipon.
19	7	2 9 A.M.	35·10	136·50	40	Nagoya.
20	"	9 52 P.M.	35·20	136·50	20	N. of Nagoya.
21	8	3 13 A.M.	35·20	137·0	10	" " "
22	"	4 54 A.M.	43·20	145·30	3	N.E. Yezo, Nemuro.
23	"	5 40 A.M.	35·30	137·0	20	N.W. Nagoya.
24	"	10 10 A.M.	35·10	136·50	10	S.W. "
25	"	5 24 P.M.	34·20	133·50	3	N. Shikoku.
26	"	10 0 P.M.	35·30	137·20	3	N.W. Nagoya.
27	9	1 15 A.M.	35·20	136·50	40	N. of "
28	"	1 37 A.M.	35·20	136·50	3	" " "
29	"	5 30 A.M.	37·25	138·50	3	Central Nipon, Echigo.
30	"	1 0 P.M.	35·10	136·50	3	Nagoya.
31	10	0 30 A.M.	35·20	136·40	10	N. of Nagoya.
32	"	8 53 A.M.	35·20	136·40	10	" " "
33	11	6 48 A.M.	36·20	140·30	20	N.W. of Tokio.
34	"	8 40 A.M.	36·10	137·20	3	Fukui Ken.

EARTHQUAKES—*continued.*

No.	Day	Time	Position of centre Latitude N.	Position of centre Longitude E.	Diameter of area shaken in nautical miles	Remarks
		H. M.				
35	11	9 20 A.M.	35·20	137·0	3	N. of Nagoya.
36	"	6 20 P.M.	37·5	137·20	3	Fukui Ken.
37	"	8 42 P.M.	35·30	137·0	3	N. of Nagoya.
38	12	0 20 P.M.	37·5	137·20	3	Fukui Ken.
39	"	?	36·5	138·10	3	Suwo, Central Nipon.
40	"	5 55 P.M.	35·30	137·0	3	N. of Nagoya.
41	13	6 42 A.M.	35·20	136·50	10	" " "
42	"	7 32 A.M.	35·30	137·0	3	" " "
43	"	8 50 A.M.	35·30	137·0	3	" " "
44	14	6 5 A.M.	39·40	141·30	3	N. Nipon, Nambu.
45	"	11 10 A.M.	35·30	137·0	3	N. of Nagoya.
46	"	11 20 P.M.	35·30	136·50	10	" " "
47	15	2 10 A.M.	35·30	136·50	10	" " "
48	"	8 30 A.M.	35·30	136·50	3	" " "
49	"	10 43 A.M.	35·30	137·20	3	N.W. of "
50	16	7 43 A.M.	35·30	136·50	3	N. " "
51	"	1 0 P.M.	35·30	136·50	3	" " "
52	"	9 10 P.M.	35·30	137·10	15	N.W. " "
53	17	5 45 A.M.	35·40	136·50	3	N. " "
54	"	7 15 A.M.	35·30	139·30	50	Central Nipon, near Tokio.
55	"	7 35 A.M.	35·20	137·0	5	N. of Nagoya.
56	"	7 55 A.M.	35·20	137·0	3	" " "
57	"	0 46 P.M.	35·20	137·0	3	" " "
58	18	3 1 A.M.	35·20	136·50	3	N.W. of "
59	"	7 56 P.M.	35·50	137·0	3	N. " "
60	19	2 1 A.M.	36·20	140·30	3	N.W. of Tokio.
61	"	1 57 P.M.	35·0	137·30	20	W. of Nagoya.
62	"	3 36 P.M.	34·30	133·50	3	Inland Sea.
63	"	8 26 P.M.	34·50	132·5	3	S.W. Nipon.
64	"	?	35·0	135·0	100	Only felt at three places on a N.W.-S.E. line.
65	"	8 42 P.M.	34·30	133·0	150	S.W. Nipon, Shikoku, to centre of Kiushiu.
66	"	10 1 P.M.	35·50	132·50	3	S.W. Shikoku.
67	"	11 0 P.M.	34·10	132·10	3	S.W. Nipon.
68	"	11 55 P.M.	35·20	137·0	3	N. of Nagoya.
69	20	1 0 A.M.	34·0	132·30	40	S.W. Nipon and W. Shikoku.
70	"	2 8 A.M.	35·20	137·0	3	N. of Nagoya.
71	"	5 2 A.M.	34·20	132·30	3	S. Nipon.
72	"	10 55 A.M.	34·50	133·20	10	" "
73	"	8 12 P.M.	33·20	131·30	3	Kiushiu.
74	"	9 30 P.M.	35·50	135·30	3	Wahayama.
75	"	11 0 P.M.	35·20	137·0	3	N. of Nagoya.
76	"	11 0 P.M.	37·20	139·40	3	Central Nipon.
77	21	2 48 A.M.	36·0	138·0	60	Central Nipon, Kofu.
78	"	2 48 A.M.	35·20	137·0	120	Gifu.
79	"	2 52 A.M.	36·30	140·10	3	N. of Tokio.
80	"	5 33 A.M.	40·0	141·0	160	N. Nipon.
81	"	6 40 P.M.	31·55	131·30	3	W. Kiushiu.
82	"	8 52 P.M.	35·20	137·0	3	N. of Nagoya.
83	"	10 37 P.M.	35·20	137·0	70	" " "
84	22	3 7 A.M.	35·20	137·0	3	" " "
85	"	6 55 A.M.	35·20	137·0	3	" " "
86	"	9 21 P.M.	34·30	132·0	3	S. Nipon.

EARTHQUAKES—*continued.*

No.	Day	Time	Position of centre		Diameter of area shaken in nautical miles	Remarks
			Latitude N.	Longitude E.		
		H. M.				
87	22	9 47 P.M.	35·20	137·0	3	N. of Nagoya.
88	23	?	37·0	140·40	60	N. and S. on coast, N. of Tokio.
89	,,	8 40 A.M.	35·10	136·50	3	W. of Nagoya.
90	,,	5 0 P.M.	35·20	137·0	40	N. ,, ,,
91	,,	8 30 P.M.	37·40	139·50	3	N. Nipon.
92	24	4 50 A.M.	35·20	137·0	3	N. of Nagoya.
93	,,	5 14 A.M.	35·20	137·0	3	,, ,, ,,
94	,,	5 0 P.M.	35·20	137·0	3	,, ,, ,,
95	25	0 40 A.M.	35·30	137·20	3	,, ,, ,,
96	,,	7 38 A.M.	35·30	136·50	10	,, ,, ,,
97	,,	8 20 A.M.	35·30	137·20	3	,, ,, ,,
98	,,	5 14 P.M.	35·20	137·0	3	,, ,, ,,
99	26	11 20 P.M.	35·20	137·0	3	,, ,, ,,
100	27	4 50 A.M.	35·20	137·0	3	,, ,, ,,
101	28	11 56 P.M.	35·20	137·0	3	,, ,, ,,

NOTE.—The reason that the diameter of the area shaken by many shocks is given as three miles is because the shock was only recorded at one place, and from investigations on areas disturbed by small shocks this number may be taken as approximately correct (see 'On a Seismic Survey made in Tokio,' *Trans. Seis. Soc.*, vol. x.).

OVERTURNING AND FRACTURING OF MASONRY AND OTHER COLUMNS.

In the Twelfth Report (1892) it was stated that the form of a wall or pier which, rather than snapping at its base, would, when subjected to horizontal reciprocating motion, be as likely to snap at any one horizontal section as at any other had been determined.

A brick building with walls approximating to this form has been designed and built by Professor K. Tatsumo on the University compound. Mr. C. A. W. Pownall, M.I.C.E., has constructed brick piers for the bridges on the Usui Pass, some of which are 110 feet high with similar sections.

An experiment relating to overturning which is in progress is to determine the relationship between the dimensions of a body and the amplitude of motion which will fail to overturn the same, no matter how short the period of motion may be.

PUBLICATION OF A SEISMOLOGICAL JOURNAL.

In consequence of many persons who took an active interest in seismology having left Japan, because work which formerly found a place in the publication of the Seismological Society now finds a place elsewhere, and for other reasons, the Seismological Society, which between 1880 and 1892 had published sixteen volumes, ceased its existence. As a certain amount of work still continues in order to bring this before those who are interested in seismology, a seismological journal has been published and the first volume already issued.

Bibliography of Spectroscopy.—Report of the Committee, consisting of Professor H. McLeod (*Chairman*), Professor W. C. Roberts-Austen (*Secretary*), Mr. H. G. Madan, *and* Dr. D. H. Nagel.

The collection and verification of titles of papers on spectroscopy have been continued during the past year, and it is expected that another instalment will be ready for printing at the next meeting.

Mathematical Functions.—Report of the Committee, consisting of Lord Rayleigh (*Chairman*), Lord Kelvin, Professor Cayley, Professor B. Price, Mr. J. W. L. Glaisher, Professor A. G. Greenhill, Professor W. M. Hicks, *and* Professor A. Lodge (*Secretary*), *appointed for the purpose of calculating Tables of certain Mathematical Functions, and, if necessary, of taking steps to carry out the Calculations, and to publish the results in an accessible form.*

The first Report of the Committee was in 1889 (at Newcastle-on-Tyne), when they published tables of $I_n(x)$ for integral values of n from 0 to 11, from $x=0$ to 6·0, at intervals of 0·2; $I_n(x)$ being defined by

$$I_n(x)=i^{-n}J_n(ix)=\frac{x^n}{2^n n!}\left\{1+\frac{x^2}{2(2n+2)}+\frac{x^4}{2\cdot4(2n+2)(2n+4)}+\ldots\right\}.$$

The present tables of $I_1(x)$ are from $x=0$ to 5·100, at intervals of ·001, and are given to nine decimal places, the last figure being approximate. They have been calculated by means of Taylor's Theorem, the successive derived functions being obtained by use of the formula

$$\frac{d}{dx}I_n(x)=\tfrac{1}{2}(I_{n-1}+I_{n+1}),$$

and of the formulæ derivable from this by successive differentiations. The values of these derived functions were checked by double calculation of the values of $I_1(x)$ halfway between those given in the 1889 table; thus, for example, $I_1(2·3)$ was calculated as $I_1(2·2+0·1)$ and also as $I_1(2·4-0·1)$. This important check confirmed at the same time the values of $I_1(x)$ which were given in the 1889 table, so that certainly the tables now given are free from any systematic error. When the present tables were finished, accidental errors were discovered and corrected by taking out first and second differences, and then, finally, the printed tables were checked by continuous addition of the first differences on Edmondson's calculating machine. It is confidently hoped, therefore, that the tables are free from serious error.

Tables of $I_0(x)$ have also been calculated, and are in a forward state, but are not quite ready for printing this year.

It is proposed to have the tables republished in book form when com-

plete, together with tables of $J_n(x)$, to six decimal places. It will be noticed that the march of $I_1(x)$ in the present table is such that interpolation by first differences only will give accurate results to six decimal places. It is proposed to preface the book of tables with a short account of the History, Theory, and Applications of the Bessel Functions, drawn up by Professor A. G. Greenhill.

The Committee are adding to the present Report a short table of $J_0(x\sqrt{i})$. If desired, a table of $J_n(x\sqrt{i})$ from $x=0$ to 6·0 at intervals of 0·2, for integral values of n from 0 to 11, could be published next year.

The Committee have expended the grant of 15*l*., and desire reappointment, with a further grant of 15*l*.

The Secretary has some copies of the 1889 Report, and will have some of the present Report, which he will be pleased to forward to anyone wishing to make use of the tables before their republication in book form. His address is, Englefield Green, Surrey.

The Committee wish to point out an error in the 1889 Report. The differential equation of which I_n is one solution has a wrong sign before its third term; it should be

$$x^2\frac{d^2u}{dx^2}+x\frac{du}{dx}-(x^2+n^2)u=0.$$

The work of calculation has been much hindered by faults in the Edmondson's calculating machine which was bought by the Committee. It has been returned to the maker several times, and has never been entirely satisfactory. Latterly the greater part of the work has been done on Professor McLeod's machine, which he is always kindly ready to lend.

x	$J_0(x\sqrt{i})$ Real part	$J_0(x\sqrt{i})$ Coefficient of i	x	$J_0(x\sqrt{i})$ Real part	$J_0(x\sqrt{i})$ Coefficient of i
0·0	+1·000 000 000	Nil	3·0	−0·221 380 250	−1·937 586 785
0·2	+0·999 975 000	−0·009 999 972	3·2	−0·564 376 430	−2·101 573 388
0·4	+0·999 600 004	−0·039 998 222	3·4	−0·968 038 995	−2·233 445 750
0·6	+0·997 975 114	−0·089 979 750	3·6	−1·435 305 322	−2·319 863 655
0·8	+0·993 601 138	−0·159 886 230	3·8	−1·967 423 273	−2·345 433 061
1·0	+0·984 381 781	−0·249 566 040	4·0	−2·563 416 557	−2·292 690 323
1·2	+0·967 629 156	−0·358 704 420	4·2	−3·219 479 832	−2·142 167 987
1·4	+0·940 075 057	−0·486 733 934	4·4	−3·928 306 622	−1·872 563 796
1·6	+0·897 891 139	−0·632 725 677	4·6	−4·678 356 937	−1·461 036 836
1·8	+0·836 721 794	−0·795 261 955	4·8	−5·453 076 175	−0·883 656 854
2·0	+0·751 734 183	−0·972 291 627	5·0	−6·230 082 479	−0·116 034 382
2·2	+0·637 690 457	−1·160 969 944	5·2	−6·980 346 403	+0·865 839 727
2·4	+0·489 047 772	−1·357 485 476	5·4	−7·667 394 351	+2·084 516 693
2·6	+0·300 092 090	−1·556 877 774	5·6	−8·246 575 962	+3·559 746 593
2·8	+0·065 112 108	−1·752 850 564	5·8	−8·664 445 263	+5·306 844 640
3·0	−0·221 380 250	−1·937 586 785	6·0	−8·858 315 966	+7·334 746 541

x	I_1x	Difference	x	I_1x	Difference
·000	Nil	500,000	·050	0·025 007 814	500,477
·001	0·000 500 000	500,001	·051	0·025 508 291	500,498
·002	0·001 000 001	1	·052	0·026 008 789	517
·003	0·001 500 002	2	·053	0·026 509 306	537
·004	0·002 000 004	4	·054	0·027 009 843	556
·005	0·002 500 008	6	·055	0·027 510 399	579
·006	0·003 000 014	7	·056	0·028 010 978	599
·007	0·003 500 021	11	·057	0·028 511 577	619
·008	0·004 000 032	14	·058	0·029 012 196	642
·009	0·004 500 046	17	·059	0·029 512 838	664
·010	0·005 000 063	20	·060	0·030 013 502	686
·011	0·005 500 083	25	·061	0·030 514 188	710
·012	0·006 000 108	29	·062	0·031 014 898	732
·013	0·006 500 137	35	·063	0·031 515 630	757
·014	0·007 000 172	39	·064	0·032 016 387	780
·015	0·007 500 211	45	·065	0·032 517 167	805
·016	0·008 000 256	51	·066	0·033 017 972	829
·017	0·008 500 307	58	·067	0·033 518 801	855
·018	0·009 000 365	64	·068	0·034 019 656	880
·019	0·009 500 429	71	·069	0·034 520 536	905
·020	0·010 000 500	79	·070	0·035 021 441	932
·021	0·010 500 579	87	·071	0·035 522 373	960
·022	0·011 000 666	94	·072	0·036 023 333	986
·023	0·011 500 760	104	·073	0·036 524 319	501,013
·024	0·012 000 864	113	·074	0·037 025 332	042
·025	0·012 500 977	122	·075	0·037 526 374	069
·026	0·013 001 099	131	·076	0·038 027 443	097
·027	0·013 501 230	142	·077	0·038 528 540	127
·028	0·014 001 372	152	·078	0·039 029 667	156
·029	0·014 501 524	163	·079	0·039 530 823	186
·030	0·015 001 687	175	·080	0·040 032 009	215
·031	0·015 501 862	186	·081	0·040 533 224	246
·032	0·016 002 048	198	·082	0·041 034 470	277
·033	0·016 502 246	211	·083	0·041 535 747	308
·034	0·017 002 457	223	·084	0·042 037 055	340
·035	0·017 502 680	236	·085	0·042 538 395	371
·036	0·018 002 916	250	·086	0·043 039 766	404
·037	0·018 503 166	264	·087	0·043 541 170	436
·038	0·019 003 430	277	·088	0·044 042 606	469
·039	0·019 503 707	293	·089	0·044 544 075	502
·040	0·020 004 000	308	·090	0·045 045 577	538
·041	0·020 504 308	323	·091	0·045 547 115	570
·042	0·021 004 631	338	·092	0·046 048 685	605
·043	0·021 504 969	355	·093	0·046 550 290	640
·044	0·022 005 324	371	·094	0·047 051 930	677
·045	0·022 505 695	390	·095	0·047 553 607	710
·046	0·023 006 085	405	·096	0·048 055 317	748
·047	0·023 506 490	423	·097	0·048 557 065	782
·048	0·024 006 913	441	·098	0·049 058 847	821
·049	0·024 507 354	460	·099	0·049 560 668	858
·050	0·025 007 814	477	·100	0·050 062 526	896

x	I_1x	Difference	x	I_1x	Difference
·100	0·050 062 526	501,896	·150	0·075 211 135	504,254
·101	0·050 564 422	932	·151	0·075 715 389	310
·102	0·051 066 354	971	·152	0·076 219 699	369
·103	0·051 568 325	502,009	·153	0·076 724 068	424
·104	0·052 070 334	050	·154	0·077 228 492	483
·105	0·052 572 384	089	·155	0·077 732 975	542
·106	0·053 074 473	129	·156	0·178 237 517	600
·107	0·053 576 602	168	·157	0·078 742 117	659
·108	0·054 078 770	210	·158	0·079 246 776	718
·109	0·054 580 980	250	·159	0·079 751 494	778
·110	0·055 083 230	290	·160	0·080 256 272	838
·111	0·055 585 520	333	·161	0·080 761 110	900
·112	0·056 087 853	375	·162	0·081 266 010	961
·113	0·056 590 228	418	·163	0·081 770 971	505,022
·114	0·057 092 646	461	·164	0·082 275 993	084
·115	0·057 595 107	504	·165	0·082 781 077	145
·116	0·058 097 611	547	·166	0·083 286 222	208
·117	0·058 600 158	590	·167	0·083 791 430	271
·118	0·059 102 748	637	·168	0·084 296 701	333
·119	0·059 605 385	680	·169	0·084 802 034	398
·120	0·060 108 065	725	·170	0·085 307 432	462
·121	0·060 610 790	771	·171	0·085 812 894	527
·122	0·061 113 561	817	·172	0·086 318 421	590
·123	0·061 616 378	862	·173	0·086 824 011	656
·124	0·062 119 240	909	·174	0·087 329 667	721
·125	0·062 622 149	957	·175	0·087 835 388	788
·126	0·063 125 106	503,004	·176	0·088 341 176	854
·127	0·063 628 110	051	·177	0·088 847 030	920
·128	0·064 131 161	101	·178	0·089 352 950	989
·129	0·064 634 262	148	·179	0·089 858 939	506,054
·130	0·065 137 410	196	·180	0·090 364 993	122
·131	0·065 640 606	247	·181	0·090 871 115	191
·132	0·066 143 853	294	·182	0·091 377 306	259
·133	0·066 647 147	347	·183	0·091 883 565	328
·134	0·067 150 494	396	·184	0·092 389 893	398
·135	0·067 653 890	447	·185	0·092 896 291	468
·136	0·068 157 337	498	·186	0·093 402 759	537
·137	0·068 660 835	552	·187	0·093 909 296	608
·138	0·069 164 387	600	·188	0·094 415 904	679
·139	0·069 667 987	652	·189	0·094 922 583	749
·140	0·070 171 639	707	·190	0·095 429 332	821
·141	0·070 675 346	760	·191	0·095 936 153	894
·142	0·071 179 106	813	·192	0·096 443 047	967
·143	0·071 682 919	867	·193	0·096 950 014	507,039
·144	0·072 186 786	921	·194	0·097 457 053	112
·145	0·072 690 707	975	·195	0.097 964 165	185
·146	0·073 194 682	504,030	·196	0·098 471 350	258
·147	0·073 698 712	084	·197	0·098 978 608	334
·148	0·074 202 796	142	·198	0·099 485 942	409
·149	0·074 706 938	197	·199	0·099 993 351	483
·150	0·075 211 135	254	·200	0·100 500 834	559

x	I_1x	Difference	x	I_1x	Difference
·200	0·100 500 834	507,559	·250	0·125 979 109	511,817
·201	0·101 008 393	507,635	·251	0·126 490 926	511,912
·202	0·101 516 028	710	·252	0·127 002 838	512,008
·203	0·102 023 738	786	·253	0·127 514 846	102
·204	0·102 531 524	865	·254	0·128 026 948	199
·205	0·103 039 389	942	·255	0·128 539 147	296
·206	0·103 547 331	508,019	·256	0·129 051 443	393
·207	0·104 055 350	097	·257	0·129 563 836	490
·208	0·104 563 447	175	·258	0·130 076 326	588
·209	0·105 071 622	256	·259	0·130 588 914	685
·210	0·105 579 878	333	·260	0·131 101 599	782
·211	0·106 088 211	413	·261	0·131 614 381	883
·212	0·106 596 624	494	·262	0·132 127 264	983
·213	0·107 105 118	573	·263	0·132 640 247	513,082
·214	0·107 613 691	654	·264	0·133 153 329	181
·215	0·108 122 345	736	·265	0·133 666 510	282
·216	0·108 631 081	818	·266	0·134 179 792	383
·217	0·109 139 899	899	·267	0·134 693 175	482
·218	0·109 648 798	981	·268	0·135 206 657	585
·219	0·110 157 779	509,064	·269	0·135 720 242	688
·220	0·110 666 843	148	·270	0·136 233 930	790
·221	0·111 175 991	231	·271	0·136 747 720	891
·222	0·111 685 222	314	·272	0·137 261 611	995
·223	0·112 194 536	398	·273	0·137 775 606	514,100
·224	0·112 703 934	484	·274	0·138 289 706	201
·225	0·113 213 418	567	·275	0·138 803 907	305
·226	0·113 722 985	654	·276	0·139 318 212	412
·227	0·114 232 639	740	·277	0·139 832 624	517
·228	0·114 742 379	825	·278	0·140 347 141	621
·229	0·115 252 204	912	·279	0·140 861 762	727
·230	0·115 762 116	998	·280	0·141 376 489	834
·231	0·116 272 114	510,086	·281	0·141 891 323	939
·232	0·116 782 200	174	·282	0·142 406 262	515,046
·233	0·117 292 374	262	·283	0·142 921 308	155
·234	0·117 802 636	350	·284	0·143 436 463	262
·235	0·118 312 986	439	·285	0·143 951 725	371
·236	0·118 823 425	528	·286	0·144 467 096	478
·237	0·119 333 953	617	·287	0·144 982 574	587
·238	0·119 844 570	707	·288	0·145 498 161	696
·239	0·120 355 277	798	·289	0·146 013 857	806
·240	0·120 866 075	889	·290	0·146 529 663	917
·241	0·121 376 964	980	·291	0·147 045 580	516,027
·242	0·121 887 944	511,071	·292	0·147 561 607	137
·243	0·122 399 015	164	·293	0·148 077 744	248
·244	0·122 910 179	256	·294	0·148 593 992	360
·245	0·123 421 435	349	·295	0·149 110 352	472
·246	0·123 932 784	440	·296	0·149 626 824	585
·247	0·124 444 224	535	·297	0·150 143 409	697
·248	0·124 955 759	628	·298	0·150 660 106	810
·249	0·125 467 387	722	·299	0·151 176 916	924
·250	0·125 979 109	817	·300	0·151 693 840	517,038

x	I_1x	Difference	x	I_1x	Difference
·300	0·151 693 840	517,038	·350	0·177 693 400	523,232
·301	0·152 210 878	153	·351	0·178 216 632	523,365
·302	0·152 728 031	267	·352	0·178 739 997	499
·303	0·153 245 298	382	·353	0·179 263 496	635
·304	0·153 762 680	497	·354	0·179 787 131	770
·305	0·154 280 177	612	·355	0·180 310 901	906
·306	0·154 797 789	729	·356	0·180 834 807	524,041
·307	0·155 315 518	846	·357	0·181 358 848	177
·308	0·155 833 364	964	·358	0·181 883 025	314
·309	0·156 351 328	518,081	·359	0·182 407 339	450
·310	0·156 869 409	197	·360	0·182 931 789	589
·311	0·157 387 606	317	·361	0·183 456 378	725
·312	0·157 905 923	434	·362	0·183 981 103	865
·313	0·158 424 357	555	·363	0·184 505 968	525,003
·314	0·158 942 912	673	·364	0·185 030 971	143
·315	0·159 461 585	793	·365	0·185 556 114	281
·316	0·159 980 378	914	·366	0·186 081 395	420
·317	0·160 499 292	519,034	·367	0·186 606 815	563
·318	0·161 018 326	155	·368	0·187 132 378	701
·319	0·161 537 481	275	·369	0·187 658 079	843
·320	0·162 056 756	399	·370	0·188 183 922	985
·321	0·162 576 155	520	·371	0·188 709 907	526,126
·322	0·163 095 675	641	·372	0·189 236 033	269
·323	0·163 615 316	766	·373	0·189 762 302	410
·324	0·164 135 082	890	·374	0·190 288 712	556
·325	0·164 654 972	520,011	·375	0·190 815 268	697
·326	0·165 174 983	137	·376	0·191 341 965	841
·327	0·165 695 120	260	·377	0·191 868 806	985
·328	0·166 215 380	386	·378	0·192 395 791	527,130
·329	0·166 735 766	512	·379	0·192 922 921	275
·330	0·167 256 278	636	·380	0·193 450 196	421
·331	0·167 776 914	763	·381	0·193 977 617	566
·332	0·168 297 677	887	·382	0·194 505 183	712
·333	0·168 818 564	521,018	·383	0·195 032 895	859
·334	0·169 339 582	142	·384	0·195 560 754	528,006
·335	0·169 860 724	270	·385	0·196 088 760	154
·336	0·170 381 994	399	·386	0·196 616 914	299
·337	0·170 903 393	527	·387	0·197 145 213	450
·338	0·171 424 920	656	·388	0·197 673 663	598
·339	0·171 946 576	785	·389	0·198 202 261	747
·340	0·172 468 361	914	·390	0·198 731 008	896
·341	0·172 990 275	522,044	·391	0·199 259 904	529,046
·342	0·173 512 319	175	·392	0·199 788 950	196
·343	0·174 034 494	305	·393	0·200 318 146	347
·344	0·174 556 799	438	·394	0·200 847 493	498
·345	0·175 079 237	568	·395	0·201 376 991	648
·346	0·175 601 805	700	·396	0·201 906 639	800
·347	0·176 124 505	832	·397	0·202 436 439	952
·348	0·176 647 337	965	·398	0·202 966 391	530,106
·349	0·177 170 302	523,098	·399	0·203 496 497	259
·350	0·177 693 400	232	·400	0·204 026 756	411

x	I_1x	Difference	x	I_1x	Difference
·400	0·204 026 756	530,411	·450	0·230 743 570	538,592
·401	0·204 557 167	530,566	·451	0·231 282 162	767
·402	0·205 087 733	720	·452	0·231 820 929	940
·403	0·205 618 453	874	·453	0·232 359 869	539,116
·404	0·206 149 327	531,028	·454	0·232 898 985	292
·405	0·206 680 355	184	·455	0·233 438 277	466
·406	0·207 211 539	340	·456	0·233 977 743	643
·407	0·207 742 879	497	·457	0·234 517 386	819
·408	0·208 274 376	654	·458	0·235 057 205	996
·409	0·208 806 030	810	·459	0·235 597 201	540,172
·410	0·209 337 840	967	·460	0·236 137 373	350
·411	0·209 869 807	532,124	·461	0·236 677 723	529
·412	0·210 401 931	284	·462	0·237 218 252	707
·413	0·210 934 215	441	·463	0·237 758 959	886
·414	0·211 466 656	600	·464	0·238 299 845	541,065
·415	0·211 999 256	760	·465	0·238 840 910	245
·416	0·212 532 016	921	·466	0·239 382 155	425
·417	0·213 064 937	533,080	·467	0·239 923 580	605
·418	0·213 598 017	242	·468	0·240 465 185	786
·419	0·214 131 259	401	·469	0·241 006 971	967
·420	0·214 664 660	563	·470	0·241 548 938	542,149
·421	0·215 198 223	724	·471	0·242 091 087	331
·422	0·215 731 947	887	·472	0·242 633 418	514
·423	0·216 265 834	534,049	·473	0·243 175 932	697
·424	0·216 799 883	213	·474	0·243 718 629	881
·425	0·217 334 096	376	·475	0·244 261 510	543,064
·426	0·217 868 472	540	·476	0·244 804 574	248
·427	0·218 403 012	705	·477	0·245 347 822	431
·428	0·218 937 717	868	·478	0·245 891 253	618
·429	0·219 472 585	535,033	·479	0·246 434 871	803
·430	0·220 007 618	199	·480	0·246 978 674	989
·431	0·220 542 817	365	·481	0·247 522 663	544,175
·432	0·221 078 182	531	·482	0·248 066 838	362
·433	0·221 613 713	698	·483	0·248 611 200	548
·434	0·222 149 411	865	·484	0·249 155 748	737
·435	0·222 685 276	536,033	·485	0·249 700 485	925
·436	0·223 221 309	199	·486	0·250 245 410	545,111
·437	0·223 757 508	369	·487	0·250 790 521	302
·438	0·224 293 877	537	·488	0·251 335 823	489
·439	0·224 830 414	707	·489	0·251 881 312	681
·440	0·225 367 121	875	·490	0·252 426 993	869
·441	0·225 903 996	537,045	·491	0·252 972 862	546,060
·442	0·226 441 041	215	·492	0·253 518 922	252
·443	0·226 978 256	387	·493	0·254 065 174	441
·444	0·227 515 643	558	·494	0·254 611 615	634
·445	0·228 053 201	730	·495	0·255 158 249	825
·446	0·228 590 931	901	·496	0·255 705 074	547,018
·447	0·229 128 832	538,073	·497	0·256 252 092	211
·448	0·229 666 905	247	·498	0·256 799 303	403
·449	0·230 205 152	418	·499	0·257 346 706	598
·450	0·230 743 570	592	·500	0·257 894 301	793

	I_1x	Difference	x	I_1x	Difference
·500	0·257 894 304	547,793	·550	0·285 530 329	558,029
·501	0·258 442 097	987	·551	0·286 088 358	558,245
·502	0·258 990 084	548,182	·552	0·286 646 603	459
·503	0·259 538 266	375	·553	0·287 205 062	676
·504	0·260 086 641	572	·554	0·287 763 738	894
·505	0·260 635 213	770	·555	0·288 322 632	559,109
·506	0·261 183 983	965	·556	0·288 881 741	328
·507	0·261 732 948	549,162	·557	0·289 441 069	546
·508	0·262 282 110	359	·558	0·290 000 615	763
·509	0·262 831 469	557	·559	0·290 560 378	982
·510	0·263 381 026	755	·560	0·291 120 360	560,202
·511	0·263 930 781	954	·561	0·291 680 562	422
·512	0·264 480 735	550,153	·562	0·292 240 984	642
·513	0·265 030 888	353	·563	0·292 801 626	862
·514	0·265 581 241	554	·564	0·293 362 488	561,084
·515	0·266 131 795	753	·565	0·293 923 572	304
·516	0·266 682 548	954	·566	0·294 484 876	527
·517	0·267 233 502	551,153	·567	0·295 046 403	750
·518	0·267 784 655	357	·568	0·295 608 153	971
·519	0·268 336 012	559	·569	0·296 170 124	562,194
·520	0·268 887 571	762	·570	0·296 732 318	419
·521	0·269 439 333	963	·571	0·297 294 737	642
·522	0·269 991 296	552,167	·572	0·297 857 379	866
·523	0·270 543 463	371	·573	0·298 420 245	563,091
·524	0·271 095 834	574	·574	0·298 983 336	317
·525	0·271 648 408	779	·575	0·299 546 653	542
·526	0·272 201 187	983	·576	0·300 110 195	768
·527	0·272 754 170	553,190	·577	0·300 673 963	995
·528	0·273 307 360	396	·578	0·301 237 958	564,222
·529	0·273 860 756	602	·579	0·301 802 180	449
·530	0·274 414 358	808	·580	0·302 366 629	677
·531	0·274 968 166	554,014	·581	0·302 931 306	905
·532	0·275 522 180	223	·582	0·303 496 211	565,134
·533	0·276 076 403	430	·583	0·304 061 345	363
·534	0·276 630 833	639	·584	0·304 626 708	593
·535	0·277 185 472	847	·585	0·305 192 301	823
·536	0·277 740 319	555,057	·586	0·305 758 124	566,053
·537	0·278 295 376	265	·587	0·306 324 177	283
·538	0·278 850 641	476	·588	0·306 890 460	515
·539	0·279 406 117	686	·589	0·307 456 975	747
·540	0·279 961 803	898	·590	0·308 023 722	978
·541	0·280 517 701	556,107	·591	0·308 590 700	567,211
·542	0·281 073 808	321	·592	0·309 157 911	445
·543	0·281 630 129	533	·593	0·309 725 356	677
·544	0·282 186 662	744	·594	0·310 293 033	912
·545	0·282 743 406	957	·595	0·310 860 945	568,146
·546	0·283 300 363	557,171	·596	0·311 429 091	381
·547	0·283 857 534	384	·597	0·311 997 472	616
·548	0·284 414 918	598	·598	0·312 566 088	851
·549	0·284 972 516	813	·599	0·313 134 939	569,087
·550	0·285 530 329	558,029	·600	0·313 704 026	323

x	I_1x	Difference	x	I_1x	Difference
·600	0·313 704 026	569,323	·650	0·342 468 895	581,701
·601	0·314 273 349	569,561	·651	0·343 050 596	581,960
·602	0·314 842 910	798	·652	0·343 632 556	582,219
·603	0·315 412 708	570,035	·653	0·344 214 775	478
·604	0·315 982 743	274	·654	0·344 797 253	739
·605	0·316 553 017	512	·655	0·345 379 992	583,000
·606	0·317 123 529	751	·656	0·345 962 992	261
·607	0·317 694 280	991	·657	0·346 546 253	522
·608	0·318 265 271	571,231	·658	0·347 129 775	784
·609	0·318 836 502	471	·659	0·347 713 559	584,046
·610	0·319 407 973	712	·660	0·348 297 605	308
·611	0·319 979 685	952	·661	0·348 881 913	572
·612	0·320 551 637	572,194	·662	0·349 466 485	835
·613	0·321 123 831	437	·663	0·350 051 320	585,099
·614	0·321 696 268	679	·664	0·350 636 419	365
·615	0·322 268 947	921	·665	0·351 221 784	629
·616	0·322 841 868	573,166	·666	0·351 807 413	895
·617	0·323 415 034	410	·667	0·352 393 308	586,160
·618	0·323 988 444	654	·668	0·352 979 468	428
·619	0·324 562 098	899	·669	0·353 565 896	694
·620	0·325 135 997	574,143	·670	0·354 152 590	960
·621	0·325 710 140	388	·671	0·354 739 550	587,228
·622	0·326 284 528	635	·672	0·355 326 778	498
·623	0·326 859 163	882	·673	0·355 914 276	765
·624	0·327 434 045	575,128	·674	0·356 502 041	588,033
·625	0·328 009 173	375	·675	0·357 090 074	304
·626	0·328 584 548	624	·676	0·357 678 378	573
·627	0·329 160 172	871	·677	0·358 266 951	845
·628	0·329 736 043	576,120	·678	0·358 855 796	589,115
·629	0·330 312 163	369	·679	0·359 444 911	386
·630	0·330 888 532	619	·680	0·360 034 297	657
·631	0·331 465 151	869	·681	0·360 623 954	931
·632	0·332 042 020	577,119	·682	0·361 213 885	590,203
·633	0·332 619 139	369	·683	0·361 804 088	476
·634	0·333 196 508	620	·684	0·362 394 564	749
·635	0·333 774 128	873	·685	0·362 985 313	591,022
·636	0·334 352 001	578,125	·686	0·363 576 335	297
·637	0·334 930 126	378	·687	0·364 167 632	573
·638	0·335 508 504	630	·688	0·364 759 205	848
·639	0·336 087 134	884	·689	0·365 351 053	592,123
·640	0·336 666 018	579,138	·690	0·365 943 176	399
·641	0·337 245 156	393	·691	0·366 535 575	677
·642	0·337 824 549	646	·692	0·367 128 252	954
·643	0·338 404 195	902	·693	0·367 721 206	593,231
·644	0·338 984 097	580,159	·694	0·368 314 437	508
·645	0·339 564 256	414	·695	0·368 907 945	788
·646	0·340 144 670	670	·696	0·369 501 733	594,067
·647	0·340 725 340	927	·697	0·370 095 800	346
·648	0·341 306 267	581,185	·698	0·370 690 146	625
·649	0·341 887 452	443	·699	0·371 284 771	906
·650	0·342 468 895	701	·700	0·371 879 677	595,187

x	I_1x	Difference	x	I_1x	Difference
·700	0·371 879 677	595,187	·750	0·401 992 463	609,808
·701	0·372 474 864	595,469	·751	0·402 602 271	610,113
·702	0·373 070 333	750	·752	0·403 212 384	417
·703	0·373 666 083	596,031	·753	0·403 822 801	723
·704	0·374 262 114	314	·754	0·404 433 524	611,029
·705	0·374 858 428	597	·755	0·405 044 553	335
·706	0·375 455 025	882	·756	0·405 655 888	641
·707	0·376 051 907	597,165	·757	0·406 267 529	948
·708	0·376 649 072	449	·758	0·406 879 477	612,255
·709	0·377 246 521	734	·759	0·407 491 732	564
·710	0·377 844 255	598,019	·760	0·408 104 296	872
·711	0·378 442 274	305	·761	0·408 717 168	613,181
·712	0·379 040 579	592	·762	0·409 330 349	491
·713	0·379 639 171	879	·763	0·409 943 840	801
·714	0·380 238 050	599,166	·764	0·410 557 641	614,110
·715	0·380 837 216	452	·765	0·411 171 751	421
·716	0·381 436 668	740	·766	0·411 786 172	733
·717	0·382 036 408	600,029	·767	0·412 400 905	615,046
·718	0·382 636 437	319	·768	0·413 015 951	356
·719	0·383 236 756	608	·769	0·413 631 307	668
·720	0·383 837 364	898	·770	0·414 246 975	983
·721	0·384 438 262	601,188	·771	0·414 862 958	616,297
·722	0·385 039 450	478	·772	0·415 479 255	610
·723	0·385 640 928	770	·773	0·416 095 865	925
·724	0·386 242 698	602,062	·774	0·416 712 790	617,239
·725	0·386 844 760	354	·775	0·417 330 029	557
·726	0·387 447 114	647	·776	0·417 947 586	871
·727	0·388 049 761	940	·777	0·418 565 457	618,188
·728	0·388 652 701	603,233	·778	0·419 183 645	504
·729	0·389 255 934	527	·779	0·419 802 149	822
·730	0·389 859 461	822	·780	0·420 420 971	619,140
·731	0·390 463 283	604,116	·781	0·421 040 111	458
·732	0·391 067 399	412	·782	0·421 659 569	777
·733	0·391 671 811	708	·783	0·422 279 346	620,097
·734	0·392 276 519	605,005	·784	0·422 899 443	417
·735	0·392 881 524	301	·785	0·423 519 860	736
·736	0·393 486 825	598	·786	0·424 140 596	621,057
·737	0·394 092 423	897	·787	0·424 761 653	379
·738	0·394 698 320	606,194	·788	0·425 383 032	701
·739	5·395 304 514	493	·789	0·426 004 733	622,022
·740	0·395 911 007	792	·790	0·426 626 755	345
·741	0·396 517 799	607,091	·791	0·427 249 100	668
·742	0·397 124 890	391	·792	0·427 871 768	992
·743	0·397 732 281	692	·793	0·428 494 760	623,315
·744	0·398 339 973	994	·794	0·429 118 075	640
·745	0·398 947 967	608,295	·795	0·429 741 715	966
·746	0·399 556 262	597	·796	0·430 365 681	624,291
·747	0·400 164 859	899	·797	0·430 989 972	616
·748	0·400 773 758	609,201	·798	0·431 614 588	944
·749	0·401 382 959	504	·799	0·432 239 532	625,270
·750	0·401 992 463	808	·800	0·432 864 802	598

x	I_1x	Difference	x	I_1x	Difference
·800	0·432 864 802	625,598	·850	0·464 555 845	642,585
·801	0·433 490 400	625,926	·851	0·465 198 430	642,938
·802	0·434 116 326	626,254	·852	0·465 841 368	643,291
·803	0·434 742 580	583	·853	0·466 484 659	645
·804	0·435 369 163	912	·854	0·467 128 304	999
·805	0·435 996 075	627,242	·855	0·467 772 303	644,353
·806	0·436 623 317	571	·856	0·468 416 656	707
·807	0·437 250 888	904	·857	0·469 061 363	645,063
·808	0·437 878 792	628,234	·858	0·469 706 426	418
·809	0·438 507 026	567	·859	0·470 351 844	775
·810	0·439 135 593	898	·860	0·470 997 619	646,132
·811	0·439 764 491	629,231	·861	0·471 643 751	489
·812	0·440 393 722	565	·862	0·472 290 240	847
·813	0·441 023 287	898	·863	0·472 937 087	647,204
·814	0·441 653 185	630,233	·864	0·473 584 291	563
·815	0·442 283 418	567	·865	0·474 231 854	922
·816	0·442 913 985	901	·866	0·474 879 776	648,282
·817	0·443 544 886	631,237	·867	0·475 528 058	643
·818	0·444 176 123	573	·868	0·476 176 701	649,004
·819	0·444 807 696	911	·869	0·476 825 705	364
·820	0·445 439 607	632,248	·870	0·477 475 069	725
·821	0·446 071 855	584	·871	0·478 124 794	650,089
·822	0·446 704 439	923	·872	0·478 774 883	451
·823	0·447 337 362	633,262	·873	0·479 425 334	814
·824	0·447 970 624	599	·874	0·480 076 148	651,178
·825	0·448 604 223	941	·875	0·480 727 326	542
·826	0·449 238 164	634,281	·876	0·481 378 868	906
·827	0·449 872 445	620	·877	0·482 030 774	652,272
·828	0·450 507 065	961	·878	0·482 683 046	638
·829	0·451 142 026	635,303	·879	0·483 335 684	653,004
·830	0·451 777 329	646	·880	0·483 988 688	371
·831	0·452 412 975	986	·881	0·484 642 059	738
·832	0·453 048 961	636,330	·882	0·485 295 797	654,105
·833	0·453 685 291	673	·883	0·485 949 902	473
·834	0·454 321 964	637,018	·884	0·486 604 375	843
·835	0·454 958 982	362	·885	0·487 259 218	655,212
·836	0·455 596 344	707	·886	0·487 914 430	582
·837	0·456 234 051	638,052	·887	0·488 570 012	952
·838	0·456 872 103	398	·888	0·489 225 964	656,322
·839	0·457 510 501	744	·889	0·489 882 286	693
·840	0·458 149 245	639,091	·890	0·490 538 979	657,066
·841	0·458 788 336	439	·891	0·491 196 045	438
·842	0·459 427 775	786	·892	0·491 853 483	810
·843	0·460 067 561	640,135	·893	0·492 511 293	658,184
·844	0·460 707 696	483	·894	0·493 169 477	559
·845	0·461 348 179	833	·895	0·493 828 036	932
·846	0·461 989 012	641,183	·896	0·494 486 968	659,306
·847	0·462 630 195	533	·897	0·495 146 274	681
·848	0·463 271 728	883	·898	0·495 805 955	660,058
·849	0·463 913 611	642,234	·899	0·496 466 013	435
·850	0·464 555 845	585	·900	0·497 126 448	811

x	I_1x	Difference	x	I_1x	Difference
·900	0·497 126 448	660,811	·950	0·530 639 310	680,309
·901	0·497 787 259	661,188	·951	0·531 319 619	680,712
·902	0·498 448 447	566	·952	0·532 000 331	681,116
·903	0·499 110 013	945	·953	0·532 681 447	520
·904	0·499 771 958	662,323	·954	0·533 362 967	925
·905	0·500 434 281	703	·955	0·534 044 892	682,330
·906	0·501 096 984	663,082	·956	0·534 727 222	737
·907	0·501 760 066	464	·957	0·535 409 959	683,143
·908	0·502 423 530	844	·958	0·536 093 102	549
·909	0·503 087 374	664,225	·959	0·536 776 651	957
·910	0·503 751 599	608	·960	0·537 460 608	684,365
·911	0·504 416 207	990	·961	0·538 144 973	774
·912	0·505 081 197	665,372	·962	0·538 829 747	685,183
·913	0·505 746 569	756	·963	0·539 514 930	592
·914	0·506 412 325	666,141	·964	0·540 200 522	686,003
·915	0·507 078 466	525	·965	0·540 886 525	413
·916	0·507 744 991	910	·966	0·541 572 938	824
·917	0·508 411 901	667,295	·967	0·542 259 762	687,235
·918	0·509 079 196	682	·968	0·542 946 997	647
·919	0·509 746 878	668,068	·969	0·543 634 644	688,061
·920	0·510 414 946	455	·970	0·544 322 705	475
·921	0·511 083 401	842	·971	0·545 011 180	885
·922	0·511 752 243	669,230	·972	0·545 700 065	689,303
·923	0·512 421 473	619	·973	0·546 389 368	717
·924	0·513 091 092	670,010	·974	0·547 079 085	690,133
·925	0·513 761 102	400	·975	0·547 769 218	548
·926	0·514 431 502	787	·976	0·548 459 766	964
·927	0·515 102 289	671,179	·977	0·549 150 730	691,383
·928	0·515 773 468	571	·978	0·549 842 113	799
·929	0·516 445 039	962	·979	0·550 533 912	692,217
·930	0·517 117 001	672,354	·980	0·551 226 129	636
·931	0·517 789 355	746	·981	0·551 918 765	693,056
·932	0·518 462 101	673,141	·982	0·552 611 821	474
·933	0·519 135 242	535	·983	0·553 305 295	896
·934	0·519 808 777	929	·984	0·553 999 191	694,316
·935	0·520 482 706	674,324	·985	0·554 693 507	737
·936	0·521 157 030	718	·986	0·555 388 244	695,158
·937	0·521 831 748	675,115	·987	0·556 083 402	583
·938	0·522 506 863	510	·988	0·556 778 985	696,004
·939	0·523 182 373	909	·989	0·557 474 989	428
·940	0·523 858 282	676,306	·990	0·558 171 417	851
·941	0·524 534 588	703	·991	0·558 868 268	697,277
·942	0·525 211 291	677,102	·992	0·559 565 545	702
·943	0·525 888 393	502	·993	0·560 263 247	698,125
·944	0·526 565 895	899	·994	0·560 961 372	555
·945	0·527 243 794	678,302	·995	0·561 659 927	979
·946	0·527 922 096	701	·996	0·562 358 906	699,408
·947	0·528 600 797	679,103	·997	0·563 058 314	834
·948	0·529 279 900	504	·998	0·563 758 148	700,264
·949	0·529 959 404	906	·999	0·564 458 412	692
·950	0·530 639 310	680,309	1·000	0·565 159 104	701,122

x	I_1x	Difference	x	I_1x	Difference
1·000	0·565 159 104	701,122	1·050	0·600 752 614	723,292
1·001	0·565 860 226	701,552	1·051	0·601 475 906	723,750
1·002	0·566 561 778	981	1·052	0·602 199 656	724,208
1·003	0·567 263 759	702,413	1·053	0·602 923 864	668
1·004	0·567 966 172	845	1·054	0·603 648 532	725,126
1·005	0·568 669 017	703,277	1·055	0·604 373 658	585
1·006	0·569 372 294	709	1·056	0·605 099 243	726,046
1·007	0·570 076 003	704,142	1·057	0·605 825 289	508
1·008	0·570 780 145	577	1·058	0·606 551 797	969
1·009	0·571 484 722	705,011	1·059	0·607 278 766	727,430
1·010	0·572 189 733	444	1·060	0·608 006 196	895
1·011	0·572 895 177	882	1·061	0·608 734 091	728,356
1·012	0·573 601 059	706,317	1·062	0·609 462 447	819
1·013	0·574 307 376	754	1·063	0·610 191 266	729,286
1·014	0·575 014 130	707,191	1·064	0·610 920 552	750
1·015	0·575 721 321	628	1·065	0·611 650 302	730,215
1·016	0·576 428 949	708,066	1·066	0·612 380 517	681
1·017	0·577 137 015	506	1·067	0·613 111 198	731,149
1·018	0·577 845 521	944	1·068	0·613 842 347	614
1·019	0·578 554 465	709,382	1·069	0·614 573 961	732,082
1·020	0·579 263 847	825	1·070	0·615 306 043	552
1·021	0·579 973 672	710,267	1·071	0·616 038 595	733,019
1·022	0·580 683 939	705	1·072	0·616 771 614	491
1·023	0·581 394 644	711,148	1·073	0·617 505 105	959
1·024	0·582 105 792	592	1·074	0·618 239 064	734,432
1·025	0·582 817 384	712,035	1·075	0·618 973 496	900
1·026	0·583 529 419	477	1·076	0·619 708 396	735,373
1·027	0·584 241 896	923	1·077	0·620 443 769	846
1·028	0·584 954 819	713,367	1·078	0·621 179 615	736,317
1·029	0·585 668 186	811	1·079	0·621 915 932	792
1·030	0·586 381 997	714,259	1·080	0·622 652 724	737,266
1·031	0·587 096 256	705	1·081	0·623 389 990	740
1·032	0·587 810 961	715,151	1·082	0·624 127 730	738,217
1·033	0·588 526 112	599	1·083	0·624 865 947	692
1·034	0·589 241 711	716,048	1·084	0·625 604 639	739,167
1·035	0·589 957 759	495	1·085	0·626 343 806	645
1·036	0·590 674 254	944	1·086	0·627 083 451	740,122
1·037	0·591 391 198	717,395	1·087	0·627 823 573	600
1·038	0·592 108 593	845	1·088	0·628 564 173	741,079
1·039	0·592 826 438	718,296	1·089	0·629 305 252	558
1·040	0·593 544 734	747	1·090	0·630 046 810	742,038
1·041	0·594 263 481	719,201	1·091	0·630 788 848	518
1·042	0·594 982 682	651	1·092	0·631 531 366	999
1·043	0·595 702 333	720,105	1·093	0·632 274 365	743,481
1·044	0·596 422 438	560	1·094	0·633 017 846	963
1·045	0·597 142 998	721,011	1·095	0·633 761 809	744,445
1·046	0·597 864 009	468	1·096	0·634 506 254	930
1·047	0·598 585 477	923	1·097	0·635 251 184	745,413
1·048	0·599 307 400	722,378	1·098	0·635 996 597	896
1·049	0·600 029 778	836	1·099	0·636 742 493	746,383
1·050	0·600 752 614	723,292	1·100	0·637 488 876	869

x	I_1x	Difference	x	I_1x	Difference
1·100	0·637 488 876	746,869	1·150	0·675 439 326	771,897
1·101	0·638 235 745	747,354	1·151	0·676 211 223	772,413
1·102	0·638 983 099	839	1·152	0·676 983 636	929
1·103	0·639 730 938	748,329	1·153	0·677 756 565	773,447
1·104	0·640 479 267	817	1·154	0·678 530 012	964
1·105	0·641 228 084	749,303	1·155	0·679 303 976	774,482
1·106	0·641 977 387	794	1·156	0·680 078 458	775,000
1·107	0·642 727 181	750,282	1·157	0·680 853 458	522
1·108	0·643 477 463	775	1·158	0·681 628 980	776,039
1·109	0·644 228 238	751,265	1·159	0·682 405 019	563
1·110	0·644 979 503	755	1·160	0·683 181 582	777,081
1·111	0·645 731 258	752,248	1·161	0·683 958 663	605
1·112	0·646 483 506	740	1·162	0·684 736 268	778,127
1·113	0·647 236 246	753,233	1·163	0·685 514 395	649
1·114	0·647 989 479	728	1·164	0·686 293 044	779,174
1·115	0·648 743 207	754,221	1·165	0·687 072 218	698
1·116	0·649 497 428	717	1·166	0·687 851 916	780,222
1·117	0·650 252 145	755,212	1·167	0·688 632 138	747
1·118	0·651 007 357	709	1·168	0·689 412 885	781,274
1·119	0·651 763 066	756,204	1·169	0·690 194 159	801
1·120	0·652 519 270	702	1·170	0·690 975 960	782,329
1·121	0·653 275 972	757,200	1·171	0·691 758 289	855
1·122	0·654 033 172	699	1·172	0·692 541 144	783,384
1·123	0·654 790 871	758,198	1·173	0·693 324 528	914
1·124	0·655 549 069	697	1·174	0·694 108 442	784,443
1·125	0·656 307 766	759,197	1·175	0·694 892 885	974
1·126	0·657 066 963	698	1·176	0·695 677 859	785,504
1·127	0·657 826 661	760,200	1·177	0·696 463 363	786,036
1·128	0·658 586 861	703	1·178	0·697 249 399	569
1·129	0·659 347 564	761,205	1·179	0·698 035 968	787,100
1·130	0·660 108 769	706	1·180	0·698 823 068	635
1·131	0·660 870 475	762,212	1·181	0·699 610 703	788,170
1·132	0·661 632 687	715	1·182	0·700 398 873	703
1·133	0·662 395 402	763,222	1·183	0·701 187 576	789,239
1·134	0·663 158 624	727	1·184	0·701 976 815	775
1·135	0·663 922 351	764,233	1·185	0·702 766 590	790,311
1·136	0·664 686 584	738	1·186	0·703 556 901	849
1·137	0·665 451 322	765,247	1·187	0·704 347 750	791,385
1·138	0·666 216 569	755	1·188	0·705 139 135	924
1·139	0·666 982 324	766,264	1·189	0·705 931 059	792,465
1·140	0·667 748 588	773	1·190	0·706 723 524	793,003
1·141	0·668 515 361	767,281	1·191	0·707 516 527	544
1·142	0·669 282 642	794	1·192	0·708 310 071	794,084
1·143	0·670 050 436	768,302	1·193	0·709 104 155	626
1·144	0·670 818 738	817	1·194	0·709 898 781	795,168
1·145	0·671 587 555	769,327	1·195	0·710 693 949	709
1·146	0·672 356 882	840	1·196	0·711 489 658	796,254
1·147	0·673 126 722	770,354	1·197	0·712 285 912	799
1·148	0·673 897 076	868	1·198	0·713 082 711	797,343
1·149	0·674 667 944	771,382	1·199	0·713 880 054	888
1·150	0·675 439 326	897	1·200	0·714 677 942	798,433

x	I_1x	Difference	x	I_1x	Difference
1·200	0·714 677 942	798,433	1·250	0·755 281 420	826,532
1·201	0·715 476 375	798,980	1·251	0·756 107 952	827,110
1·202	0·716 275 355	799,528	1·252	0·756 935 062	690
1·203	0·717 074 883	800,075	1·253	0·757 762 752	828,270
1·204	0·717 874 958	623	1·254	0·758 591 022	849
1·205	0·718 675 581	801,172	1·255	0·759 419 871	829,431
1·206	0·719 476 753	722	1·256	0·760 249 302	830,012
1·207	0·720 278 475	802,272	1·257	0·761 079 314	594
1·208	0·721 080 747	823	1·258	0·761 909 908	831,177
1·209	0·721 883 570	803,374	1·259	0·762 741 085	761
1·210	0·722 686 944	927	1·260	0·763 572 846	832,346
1·211	0·723 490 871	804,480	1·261	0·764 405 192	931
1·212	0·724 295 351	805,033	1·262	0·765 238 123	833,514
1·213	0·725 100 384	586	1·263	0·766 071 637	834,100
1·214	0·725 905 970	806,140	1·264	0·766 905 737	688
1·215	0·726 712 110	697	1·265	0·767 740 425	835,277
1·216	0·727 518 807	807,254	1·266	0·768 575 702	864
1·217	0·728 326 061	808	1·267	0·769 411 566	836,453
1·218	0·729 133 869	808,366	1·268	0·770 248 019	837,040
1·219	0·729 942 235	925	1·269	0·771 085 059	632
1·220	0·730 751 160	809,483	1·270	0·771 922 691	838,223
1·221	0·731 560 643	810,042	1·271	0·772 760 914	815
1·222	0·732 370 685	600	1·272	0·773 599 729	839,406
1·223	0·733 181 285	811,162	1·273	0·774 439 135	998
1·224	0·733 992 447	723	1·274	0·775 279 133	840,592
1·225	0·734 804 170	812,284	1·275	0·776 119 725	841,186
1·226	0·735 616 454	846	1·276	0·776 960 911	782
1·227	0·736 429 300	813,410	1·277	0·777 802 693	842,377
1·228	0·737 242 710	973	1·278	0·778 645 070	972
1·229	0·738 056 683	814,536	1·279	0·779 488 042	843,568
1·230	0·738 871 219	815,104	1·280	0·780 331 610	844,166
1·231	0·739 686 323	666	1·281	0·781 175 776	765
1·232	0·740 501 989	816,233	1·282	0·782 020 541	845,364
1·233	0·741 318 222	800	1·283	0·782 865 905	961
1·234	0·742 135 022	817,368	1·284	0·783 711 866	846,561
1·235	0·742 952 390	935	1·285	0·784 558 427	847,164
1·236	0·743 770 325	818,504	1·286	0·785 405 591	765
1·237	0·744 588 829	819,073	1·287	0·786 253 356	848,366
1·238	0·745 407 902	643	1·288	0·787 101 722	969
1·239	0·746 227 545	820,213	1·289	0·787 950 691	849,572
1·240	0·747 047 758	785	1·290	0·788 800 263	850,176
1·241	0·747 868 543	821,357	1·291	0·789 650 439	781
1·242	0·748 689 900	930	1·292	0·790 501 220	851,387
1·243	0·749 511 830	822,503	1·293	0·791 352 607	992
1·244	0·750 334 333	823,076	1·294	0·792 204 599	852,599
1·245	0·751 157 409	651	1·295	0·793 057 198	853,206
1·246	0·751 981 060	824,225	1·296	0·793 910 404	814
1·247	0·752 805 285	802	1·297	0·794 764 218	854,423
1·248	0·753 630 087	825,378	1·298	0·795 618 641	855,032
1·249	0·754 455 465	955	1·299	0·796 473 673	641
1·250	0·755 281 420	826,532	1·300	0·797 329 314	856,253

x	I_1x	Difference	x	I_1x	Difference
1·300	0·797 329 314	856,253	1·350	0·840 904 230	887,659
1·301	0·798 185 567	856,865	1·351	0·841 791 889	888,304
1·302	0·799 042 432	857,476	1·352	0·842 680 193	949
1·303	0·799 899 908	858,089	1·353	0·843 569 142	889,597
1·304	0·800 757 997	703	1·354	0·844 458 739	890,244
1·305	0·801 616 700	859,317	1·355	0·845 348 983	895
1·306	0·802 476 017	931	1·356	0·846 239 878	891,541
1·307	0·803 335 948	860,547	1·357	0·847 131 419	892,192
1·308	0·804 196 495	861,164	1·358	0·848 023 611	843
1·309	0·805 057 659	779	1·359	0·848 916 454	893,495
1·310	0·805 919 438	862,397	1·360	0·849 809 949	894,147
1·311	0·806 781 835	863,015	1·361	0·850 704 096	799
1·312	0·807 644 850	633	1·362	0·851 598 895	895,453
1·313	0·808 508 483	864,254	1·363	0·852 494 348	896,108
1·314	0·809 372 737	875	1·364	0·853 390 456	761
1·315	0·810 237 612	865,493	1·365	0·854 287 217	897,417
1·316	0·811 103 105	866,117	1·366	0·855 184 634	898,073
1·317	0·811 969 222	738	1·367	0·856 082 707	732
1·318	0·812 835 960	867,362	1·368	0·856 981 439	899,388
1·319	0·813 703 322	985	1·369	0·857 880 827	900,045
1·320	0·814 571 307	868,610	1·370	0·858 780 872	707
1·321	0·815 439 917	869,234	1·371	0·859 681 579	901,367
1·322	0·816 309 151	859	1·372	0·860 582 946	902,025
1·323	0·817 179 010	870,486	1·373	0·861 484 971	687
1·324	0·818 049 496	871,113	1·374	0·862 387 658	903,349
1·325	0·818 920 609	742	1·375	0·863 291 007	904,012
1·326	0·819 792 351	872,368	1·376	0·864 195 019	676
1·327	0·820 664 719	999	1·377	0·865 099 695	905,341
1·328	0·821 537 718	873,627	1·378	0·866 005 036	906,005
1·329	0·822 411 345	874,258	1·379	0·866 911 041	669
1·330	0·823 285 603	890	1·380	0·867 817 710	907,336
1·331	0·824 160 493	875,522	1·381	0·868 725 046	908,004
1·332	0·825 036 015	876,154	1·382	0·869 633 050	670
1·333	0·825 912 169	786	1·383	0·870 541 720	909,340
1·334	0·826 788 955	877,422	1·384	0·871 451 060	910,008
1·335	0·827 666 377	878,057	1·385	0·872 361 068	678
1·336	0·828 544 434	689	1·386	0·873 271 746	911,349
1·337	0·829 423 123	879,328	1·387	0·874 183 095	912,020
1·338	0·830 302 451	962	1·388	0·875 095 115	693
1·339	0·831 182 413	880,602	1·389	0·876 007 808	913,364
1·340	0·832 063 015	881,238	1·390	0·876 921 172	914,040
1·341	0·832 944 253	879	1·391	0·877 835 212	712
1·342	0·833 826 132	882,516	1·392	0·878 749 924	915,387
1·343	0·834 708 648	883,157	1·393	0·879 665 311	916,063
1·344	0·835 591 805	799	1·394	0·880 581 374	740
1·345	0·836 475 604	884,439	1·395	0·881 498 114	917,416
1·346	0·837 360 043	885,082	1·396	0·882 415 530	918,095
1·347	0·838 245 125	724	1·397	0·883 333 625	772
1·348	0·839 130 849	886,369	1·398	0·884 252 397	919,453
1·349	0·840 017 218	887,012	1·399	0·885 171 850	920,131
1·350	0·840 904 230	659	1·400	0·886 091 981	813

x	I_1x	Difference	x	I_1x	Difference
1·400	0·886 091 981	920,813	1·450	0·932 981 780	955,788
1·401	0·887 012 794	921,495	1·451	0·933 937 568	956,507
1·402	0·887 934 289	922,176	1·452	0·934 894 075	957,226
1·403	0·888 856 465	859	1·453	0·935 851 301	946
1·404	0·889 779 324	923,542	1·454	0·936 809 247	958,666
1·405	0·890 702 866	924,228	1·455	0·937 767 913	959,388
1·406	0·891 627 094	913	1·456	0·938 727 301	960,111
1·407	0·892 552 007	925,597	1·457	0·939 687 412	834
1·408	0·893 477 604	926,284	1·458	0·940 648 246	961,559
1·409	0·894 403 888	972	1·459	0·941 609 805	962,282
1·410	0·895 330 860	927,660	1·460	0·942 572 087	963,008
1·411	0·896 258 520	928,349	1·461	0·943 535 095	732
1·412	0·897 186 869	929,039	1·462	0·944 498 827	964,462
1·413	0·898 115 908	728	1·463	0·945 463 289	965,189
1·414	0·899 045 636	930,418	1·464	0·946 428 478	917
1·415	0·899 976 054	931,112	1·465	0·947 394 395	966,648
1·416	0·900 907 166	802	1·466	0·948 361 043	967,374
1·417	0·901 838 968	932,498	1·467	0·949 328 417	968,108
1·418	0·902 771 466	933,190	1·468	0·950 296 525	838
1·419	0·903 704 656	884	1·469	0·951 265 363	969,572
1·420	0·904 638 540	934,581	1·470	0·952 234 935	970,304
1·421	0·905 573 121	935,277	1·471	0·953 205 239	971,039
1·422	0·906 508 398	973	1·472	0·954 176 278	773
1·423	0·907 444 371	936,670	1·473	0·955 148 051	972,506
1·424	0·908 381 041	937,370	1·474	0·956 120 557	973,244
1·425	0·909 318 411	938,069	1·475	0·957 093 801	981
1·426	0·910 256 480	767	1·476	0·958 067 782	974,720
1·427	0·911 195 247	939,469	1·477	0·959 042 502	975,457
1·428	0·912 134 716	940,171	1·478	0·960 017 959	976,196
1·429	0·913 074 887	871	1·479	0·960 994 155	937
1·430	0·914 015 758	941,575	1·480	0·961 971 092	977,678
1·431	0·914 957 333	942,278	1·481	0·962 948 770	978,420
1·432	0·915 899 611	982	1·482	0·963 927 190	979,160
1·433	0·916 842 593	943,689	1·483	0·964 906 350	905
1·434	0·917 786 282	944,393	1·484	0·965 886 255	980,647
1·435	0·918 730 675	945,099	1·485	0·966 866 902	981,393
1·436	0·919 675 774	808	1·486	0·967 848 295	982,140
1·437	0·920 621 582	946,515	1·487	0·968 830 435	883
1·438	0·921 568 097	947,223	1·488	0·969 813 318	983,633
1·439	0·922 515 320	935	1·489	0·970 796 951	984,379
1·440	0·923 463 255	948,645	1·490	0·971 781 330	985,129
1·441	0·924 411 900	949,353	1·491	0·972 766 459	876
1·442	0·925 361 253	950,068	1·492	0·973 752 335	986,629
1·443	0·926 311 321	779	1·493	0·974 738 964	987,379
1·444	0·927 262 100	951,493	1·494	0·975 726 343	988,131
1·445	0·928 213 593	952,206	1·495	0·976 714 474	881
1·446	0·929 165 799	921	1·496	0·977 703 355	989,637
1·447	0·930 118 720	953,636	1·497	0·978 692 992	990,390
1·448	0·931 072 356	954,353	1·498	0·979 683 382	991,145
1·449	0·932 026 709	955,071	1·499	0·980 674 527	901
1·450	0·932 981 780	788	1·500	0·981 666 428	992,657

x	I_1x	Difference	x	I_1x	Difference
1·500	0·981 666 428	992,657	1·550	1·032 242 518	1,031,498
1·501	0·982 659 085	993,416	1·551	1·033 274 016	1,032,296
1·502	0·983 652 501	994,173	1·552	1·034 306 312	1,033,095
1·503	0·984 646 674	931	1·553	1·035 339 407	893
1·504	0·985 641 605	995,691	1·554	1·036 373 300	1,034,693
1·505	0·986 637 296	996,451	1·555	1·037 407 993	1,035,495
1·506	0·987 633 747	997,212	1·556	1·038 443 488	1,036,295
1·507	0·988 630 959	975	1·557	1·039 479 783	1,037,098
1·508	0·989 628 934	998,737	1·558	1·040 516 881	901
1·509	0·990 627 671	999,499	1·559	1·041 554 782	1,038,706
1·510	0·991 627 170	1,000,266	1·560	1·042 593 488	1,039,511
1·511	0·992 627 436	1,001,031	1·561	1·043 632 999	1,040,317
1·512	0·993 628 467	796	1·562	1·044 673 316	1,041,122
1·513	0·994 630 263	1,002,563	1·563	1·045 714 438	930
1·514	0·995 632 826	1,003,330	1·564	1·046 756 368	1,042,738
1·515	0·996 636 156	1,004,099	1·565	1·047 799 106	1,043,547
1·516	0·997 640 255	868	1·566	1·048 842 653	1,044,357
1·517	0·998 645 123	1,005,639	1·567	1·049 887 010	1,045,169
1·518	0·999 650 762	1,006,409	1·568	1·050 932 179	980
1·519	1·000 657 171	1,007,180	1·569	1·051 978 159	1,046,792
1·520	1·001 664 351	953	1·570	1·053 024 951	1,047,604
1·521	1·002 672 304	1,008,726	1·571	1·054 072 555	1,048,419
1·522	1·003 681 030	1,009,498	1·572	1·055 120 974	1,049,235
1·523	1·004 690 528	1,010,275	1·573	1·056 170 209	1,050,051
1·524	1·005 700 803	1,011,049	1·574	1·057 220 260	866
1·525	1·006 711 852	826	1·575	1·058 271 126	1,051,683
1·526	1·007 723 678	1,012,605	1·576	1·059 322 809	1,052,502
1·527	1·008 736 283	1,013,382	1·577	1·060 375 311	1,053,322
1·528	1·009 749 665	1,014,159	1·578	1·061 428 633	1,054,140
1·529	1·010 763 824	941	1·579	1·062 482 773	962
1·530	1·011 778 765	1,015,720	1·580	1·063 537 735	1,055,784
1·531	1·012 794 485	1,016,500	1·581	1·064 593 519	1,056,605
1·532	1·013 810 985	1,017,285	1·582	1·065 650 124	1,057,429
1·533	1·014 828 270	1,018,066	1·583	1·066 707 553	1,058,254
1·534	1·015 846 336	850	1·584	1·067 765 807	1,059,078
1·535	1·016 865 186	1,019,632	1·585	1·068 824 885	905
1·536	1·017 884 818	1,020,421	1·586	1·069 884 790	1,060,731
1·537	1·018 905 239	1,021,205	1·587	1·070 945 521	1,061,558
1·538	1·019 926 444	992	1·588	1·072 007 079	1,062,386
1·539	1·020 948 436	1,022,780	1·589	1·073 069 465	1,063,216
1·540	1·021 971 216	1,023,570	1·590	1·074 132 681	1,064,047
1·541	1·022 994 786	1,024,357	1·591	1·075 196 728	877
1·542	1·024 019 143	1,025,148	1·592	1·076 261 605	1,065,708
1·543	1·025 044 291	939	1·593	1·077 327 313	1,066,542
1·544	1·026 070 230	1,026,730	1·594	1·078 393 855	1,067,374
1·545	1·027 096 960	1,027,523	1·595	1·079 461 229	1,068,210
1·546	1·028 124 483	1,028,319	1·596	1·080 529 439	1,069,044
1·547	1·029 152 802	1,029,109	1·597	1·081 598 483	880
1·548	1·030 181 911	906	1·598	1·082 668 363	1,070,717
1·549	1·031 211 817	1,030,701	1·599	1·083 739 080	1,071,555
1·550	1·032 242 518	1,031,498	1·600	1·084 810 635	1,072,393

x	I_1x	Difference	x	I_1x	Difference
1·600	1·084 810 635	1,072,393	1·650	1·139 475 574	1,115,429
1·601	1·085 883 028	1,073,233	1·651	1·140 591 003	1,116,312
1·602	1·086 956 261	1,074,074	1·652	1·141 707 315	1,117,195
1·603	1·088 030 335	914	1·653	1·142 824 510	1,118,081
1·604	1·089 105 249	1,075,756	1·654	1·143 942 591	967
1·605	1·090 181 005	1,076,600	1·655	1·145 061 558	1,119,854
1·606	1·091 257 605	1,077,442	1·656	1·146 181 412	1,120,741
1·607	1·092 335 047	1,078,288	1·657	1·147 302 153	1,121,630
1·608	1·093 413 335	1,079,133	1·658	1·148 423 783	1,122,519
1·609	1·094 492 468	979	1·659	1·149 546 302	1,123,410
1·610	1·095 572 447	1,080,826	1·660	1·150 669 712	1,124,300
1·611	1·096 653 273	1,081,675	1·661	1·151 794 012	1,125,192
1·612	1·097 734 948	1,082,523	1·662	1·152 919 204	1,126,087
1·613	1·098 817 471	1,083,373	1·663	1·154 045 291	981
1·614	1·099 900 844	1,084,223	1·664	1·155 172 272	1,127,874
1·615	1·100 985 067	1,085,076	1·665	1·156 300 146	1,128,770
1·616	1·102 070 143	928	1·666	1·157 428 916	1,129,668
1·617	1·103 156 071	1,086,781	1·667	1·158 558 584	1,130,565
1·618	1·104 242 852	1,087,635	1·668	1·159 689 149	1,131,460
1·619	1·105 330 487	1,088,490	1·669	1·160 820 609	1,132,364
1·620	1·106 418 977	1,089,346	1·670	1·161 952 973	1,133,263
1·621	1·107 508 323	1,090,202	1·671	1·163 086 236	1,134,163
1·622	1·108 598 525	1,091,060	1·672	1·164 220 399	1,135,066
1·623	1·109 689 585	918	1·673	1·165 355 465	969
1·624	1·110 781 503	1,092,779	1·674	1·166 491 434	1,136,872
1·625	1·111 874 282	1,093,638	1·675	1·167 628 306	1,137,779
1·626	1·112 967 920	1,094,499	1·676	1·168 766 085	1,138,683
1·627	1·114 062 419	1,095,361	1·677	1·169 904 768	1,139,590
1·628	1·115 157 780	1,096,223	1·678	1·171 044 358	1,140,498
1·629	1·116 254 003	1,097,088	1·679	1·172 184 856	1,141,405
1·630	1·117 351 091	952	1·680	1·173 326 261	1,142,314
1·631	1·118 449 043	1,098,818	1·681	1·174 468 575	1,143,226
1·632	1·119 547 861	1,099,683	1·682	1·175 611 801	1,144,136
1·633	1·120 647 544	1,100,551	1·683	1·176 755 937	1,145,049
1·634	1·121 748 095	1,101,419	1·684	1·177 900 986	962
1·635	1·122 849 514	1,102,290	1·685	1·179 046 948	1,146,877
1·636	1·123 951 804	1,103,157	1·686	1·180 193 825	1,147,790
1·637	1·125 054 961	1,104,029	1·687	1·181 341 615	1,148,706
1·638	1·126 158 990	900	1·688	1·182 490 321	1,149,623
1·639	1·127 263 890	1,105,774	1·689	1·183 639 944	1,150,542
1·640	1·128 369 664	1,106,646	1·690	1·184 790 486	1,151,459
1·641	1·129 476 310	1,107,521	1·691	1·185 941 945	1,152,379
1·642	1·130 583 831	1,108,395	1·692	1·187 094 324	1,153,299
1·643	1·131 692 226	1,109,271	1·693	1·188 247 623	1,154,220
1·644	1·132 801 497	1,110,148	1·694	1·189 401 843	1,155,143
1·645	1·133 911 645	1,111,027	1·695	1·190 556 986	1,156,066
1·646	1·135 022 672	905	1·696	1·191 713 052	990
1·647	1·136 134 577	1,112,785	1·697	1·192 870 042	1,157,915
1·648	1·137 247 362	1,113,666	1·698	1·194 027 957	1,158,840
1·649	1·138 361 028	1,114,546	1·699	1·195 186 797	1,159,768
1·650	1·139 475 574	1,115,429	1·700	1·196 346 565	1,160,695

x	I_1x	Difference	x	I_1x	Difference
1·700	1·196 346 565	1,160,695	1·750	1·255 537 513	1,208,290
1·701	1·197 507 260	1,161,625	1·751	1·256 745 803	1,209,265
1·702	1·198 668 885	1,162,554	1·752	1·257 955 068	1,210,243
1·703	1·199 831 439	1,163,485	1·753	1·259 165 311	1,211,223
1·704	1·200 994 924	1,164,417	1·754	1·260 376 534	1,212,202
1·705	1·202 159 341	1,165,349	1·755	1·261 588 736	1,213,182
1·706	1·203 324 690	1,166,282	1·756	1·262 801 918	1,214,160
1·707	1·204 490 972	1,167,217	1·757	1·264 016 078	1,215,145
1·708	1·205 658 189	1,168,152	1·758	1·265 231 223	1,216,128
1·709	1·206 826 341	1,169,088	1·759	1·266 447 351	1,217,112
1·710	1·207 995 429	1,170,026	1·760	1·267 664 463	1,218,097
1·711	1·209 165 455	963	1·761	1·268 882 560	1,219,083
1·712	1·210 336 418	1,171,902	1·762	1·270 101 643	1,220,069
1 713	1·211 508 320	1,172,843	1·763	1·271 321 712	1,221,059
1·714	1·212 681 163	1,173,782	1·764	1·272 542 771	1,222,047
1·715	1·213 854 945	1,174,727	1·765	1·273 764 818	1,223,036
1·716	1·215 029 672	1,175,667	1·766	1·274 987 854	1,224,029
1·717	1·216 205 339	1,176,611	1·767	1·276 211 883	1,225,020
1·718	1·217 381 950	1,177,557	1·768	1·277 436 903	1,226,013
1·719	1·218 559 507	1,178,502	1·769	1·278 662 916	1,227,007
1·720	1·219 738 009	1,179,449	1·770	1·279 889 923	1,228,001
1·721	1·220 917 458	1,180,397	1·771	1·281 117 924	997
1·722	1·222 097 855	1,181,344	1·772	1·282 346 921	1,229,995
1·723	1·223 279 199	1,182,294	1·773	1·283 576 916	1,230,993
1·724	1·224 461 493	1,183,245	1·774	1·284 807 909	1,231,991
1·725	1·225 644 738	1,184,195	1·775	1·286 039 900	1,232,991
1·726	1·226 828 933	1,185,148	1·776	1·287 272 891	1,233,992
1·727	1·228 014 081	1,186,101	1·777	1·288 506 883	1,234,994
1·728	1·229 200 182	1,187,056	1·778	1·289 741 877	1,235,997
1·729	1·230 387 238	1,188,011	1·779	1·290 977 874	1,237,000
1·730	1·231 575 249	966	1·780	1·292 214 874	1,238,006
1·731	1·232 764 215	1,189,923	1·781	1·293 452 880	1,239,011
1·732	1·233 954 138	1,190,882	1·782	1·294 691 891	1,240,018
1·733	1·235 145 020	1,191,841	1·783	1·295 931 909	1,241,026
1·734	1·236 336 861	1,192,801	1·784	1·297 172 935	1,242,034
1·735	1·237 529 662	1,193,761	1·785	1·298 414 969	1,243,045
1·736	1·238 723 423	1,194,723	1·786	1·299 658 014	1,244,055
1·737	1·239 918 146	1,195,686	1·787	1·300 902 069	1,245,068
1·738	1·241 113 832	1,196,650	1·788	1·302 147 137	1,246,079
1·739	1·242 310 482	1,197,614	1·789	1·303 393 216	1,247,094
1·740	1·243 508 096	1,198,581	1·790	1·304 640 310	1,248,109
1·741	1·244 706 677	1,199,546	1·791	1·305 888 419	1,249,125
1·742	1·245 906 223	1,200,515	1·792	1·307 137 544	1,250,141
1·743	1·247 106 738	1,201,483	1·793	1·308 387 685	1,251,159
1·744	1·248 308 221	1,202,452	1·794	1·309 638 844	1,252,178
1·745	1·249 510 673	1.203,423	1·795	1·310 891 022	1,253,198
1·746	1·250 714 096	1,204,395	1·796	1·312 144 220	1,254,219
1·747	1·251 918 491	1,205,366	1·797	1·313 398 439	1,255,240
1·748	1·253 123 857	1,206,340	1·798	1·314 653 679	1,256,264
1·749	1·254 330 197	1,207,316	1·799	1·315 909 943	1,257,287
1·750	1·255 537 513	1,208,290	1·800	1·317 167 230	1,258,313

x	I_1x	Difference	x	I_1x	Difference
1·800	1·317 167 230	1,258,313	1·850	1·381 359 709	1,310,868
1·801	1·318 425 543	1,259,338	1·851	1·382 670 577	1,311,948
1·802	1·319 684 881	1,260,366	1·852	1·383 982 525	1,313,026
1·803	1·320 945 247	1,261,393	1·853	1·385 295 551	1,314,105
1·804	1·322 206 640	1,262,422	1·854	1·386 609 656	1,315,187
1·805	1·323 469 062	1,263,452	1·855	1·387 924 843	1,316,268
1·806	1·324 732 514	1,264,483	1·856	1·389 241 111	1,317,351
1·807	1·325 996 997	1,265,515	1·857	1·390 558 462	1,318,437
1·808	1·327 262 512	1,266,549	1·858	1·391 876 899	1,319,520
1·809	1·328 529 061	1,267,583	1·859	1·393 196 419	1,320,607
1·810	1·329 796 644	1,268,618	1·860	1·394 517 026	1,321,694
1·811	1·331 065 262	1,269,653	1·861	1·395 838 720	1,322,782
1·812	1·332 334 915	1,270,690	1·862	1·397 161 502	1,323,872
1·813	1·333 605 605	1,271,729	1·863	1·398 485 374	1,324,964
1·814	1·334 877 334	1,272,769	1·864	1·399 810 338	1,326,054
1·815	1·336 150 103	1,273,808	1·865	1·401 136 392	1,327,147
1·816	1·337 423 911	1,274,850	1·866	1·402 463 539	1,328,241
1·817	1·338 698 761	1,275,892	1·867	1·403 791 780	1,329,336
1·818	1·339 974 653	1,276,935	1·868	1·405 121 116	1,330,431
1·819	1·341 251 588	1,277,980	1·869	1·406 451 547	1,331,529
1·820	1·342 529 568	1,279,024	1·870	1·407 783 076	1,332,626
1·821	1·343 808 592	1,280,071	1·871	1·409 115 702	1,333,725
1·822	1·345 088 663	1,281,118	1·872	1·410 449 427	1,334,826
1·823	1·346 369 781	1,282,168	1·873	1·411 784 253	1,335,927
1·824	1·347 651 949	1,283,217	1·874	1·413 120 180	1,337,030
1·825	1·348 935 166	1,284,267	1·875	1·414 457 210	1,338,131
1·826	1·350 219 433	1,285,319	1·876	1·415 795 341	1,339,236
1·827	1·351 504 752	1,286,371	1·877	1·417 134 577	1,340,344
1·828	1·352 791 123	1,287,425	1·878	1·418 474 921	1,341,449
1·829	1·354 078 548	1,288,479	1·879	1·419 816 370	1,342,557
1·830	1·355 367 027	1,289,535	1·880	1·421 158 927	1,343,666
1·831	1·356 656 562	1,290,593	1·881	1·422 502 593	1,344,775
1·832	1·357 947 155	1,291,650	1·882	1·423 847 368	1,345,887
1·833	1·359 238 805	1,292,709	1·883	1·425 193 255	1,346,999
1·834	1·360 531 514	1,293,768	1·884	1·426 540 254	1,348,113
1·835	1·361 825 282	1,294,829	1·885	1·427 888 367	1,349,226
1·836	1·363 120 111	1,295,893	1·886	1·429 237 593	1,350,341
1·837	1·364 416 004	1,296,955	1·887	1·430 587 934	1,351,460
1·838	1·365 712 959	1,298,018	1·888	1·431 939 394	1,352,575
1·839	1·367 010 977	1,299,084	1·889	1·433 291 969	1,353,694
1·840	1·368 310 061	1,300,149	1·890	1·434 645 663	1,354,814
1·841	1·369 610 210	1,301,217	1·891	1·436 000 477	1,355,935
1·842	1·370 911 427	1,302,285	1·892	1·437 356 412	1,357,056
1·843	1·372 213 712	1,303,354	1·893	1·438 713 468	1,358,180
1·844	1·373 517 066	1,304,426	1·894	1·440 071 648	1,359,305
1·845	1·374 821 492	1,305,496	1·895	1·441 430 953	1,360,429
1·846	1·376 126 988	1,306,569	1·896	1·442 791 382	1,361,555
1·847	1·377 433 557	1,307,641	1·897	1·444 152 937	1,362,683
1·848	1·378 741 198	1,308,717	1·898	1·445 515 620	1,363,812
1·849	1·380 049 915	1,309,794	1·899	1·446 879 432	1,364,941
1·850	1·381 359 709	1,310,868	1·900	1·448 244 373	1,366,071

x	I_1x	Difference	x	I_1x	Difference
1·900	1·448 244 373	1,366,071	1·950	1·517 956 370	1,424,038
1·901	1·449 610 444	1,367,204	1·951	1·519 380 408	1,425,226
1·902	1·450 977 648	1,368,337	1·952	1·520 805 634	1,426,415
1·903	1·452 345 985	1,369,470	1·953	1·522 232 049	1,427,606
1·904	1·453 715 455	1,370,606	1·954	1·523 659 655	1,428,798
1·905	1·455 086 061	1,371,742	1·955	1·525 088 453	1,429,991
1·906	1·456 457 803	1,372,879	1·956	1·526 518 444	1,431,186
1·907	1·457 830 682	1,374,018	1·957	1·527 949 630	1,432,380
1·908	1·459 204 700	1,375,159	1·958	1·529 382 010	1,433,577
1·909	1·460 579 859	1,376,298	1·959	1·530 815 587	1,434,775
1·910	1·461 956 157	1,377,440	1·960	1·532 250 362	1,435,973
1·911	1·463 333 597	1,378,582	1·961	1·533 686 335	1,437,173
1·912	1·464 712 179	1,379,728	1·962	1·535 123 508	1,438,374
1·913	1·466 091 907	1,380,873	1·963	1·536 561 882	1,439,576
1·914	1·467 472 780	1,282,019	1·964	1·538 001 458	1,440,781
1·915	1·468 854 799	1,383,165	1·965	1·539 442 239	1,441,985
1·916	1·470 237 964	1,384,315	1·966	1·540 884 224	1,443,190
1·917	1·471 622 279	1,385,464	1·967	1·542 327 414	1,444,397
1·918	1·473 007 743	1,386,615	1·968	1·543 771 811	1,445,607
1·919	1·474 394 358	1,387,767	1·969	1·545 217 418	1,446,815
1·920	1·475 782 125	1,388,919	1·970	1·546 664 233	1,448,023
1·921	1·477 171 044	1,390,074	1·971	1·548 112 256	1,449,237
1·922	1·478 561 118	1,391,229	1·972	1·549 561 493	1,450,451
1·923	1·479 952 347	1,392,386	1·973	1·551 011 944	1,451,663
1·924	1·481 344 733	1,393,543	1·974	1·552 463 607	1,452,878
1·925	1·482 738 276	1,394,703	1·975	1·553 916 485	1,454,096
1·926	1·484 132 979	1,395,862	1·976	1·555 370 581	1,455,313
1·927	1·485 528 841	1,397,023	1·977	1·556 825 894	1,456,531
1·928	1·486 925 864	1,398,184	1·978	1·558 282 425	1,457,751
1·929	1·488 324 048	1,399,347	1·979	1·559 740 176	1,458,972
1·930	1·489 723 395	1,400,513	1·980	1·561 199 148	1,460,195
1·931	1·491 123 908	1,401,677	1·981	1·562 659 343	1,461,419
1·932	1·492 525 585	1,402,844	1·982	1·564 120 762	1,462,643
1·933	1·493 928 429	1,404,012	1·983	1·565 583 405	1,463,868
1·934	1·495 332 441	1,405,181	1·984	1·567 047 273	1,465,096
1·935	1·496 737 622	1,406,350	1·985	1·568 512 369	1,466,325
1·936	1·498 143 972	1,407,522	1·986	1·569 978 694	1,467,552
1·937	1·499 551 494	1,408,694	1·987	1·571 446 246	1,468,783
1·938	1·500 960 188	1,409,867	1·988	1·572 915 029	1,470,015
1·939	1·502 370 055	1,411,041	1·989	1·574 385 044	1,471,249
1·940	1·503 781 096	1,412,218	1·990	1·575 856 293	1,472,483
1·941	1·505 193 314	1,413,396	1·991	1·577 328 776	1,473,718
1·942	1·506 606 710	1,414,573	1·992	1·578 802 494	1,474,955
1·943	1·508 021 283	1,415,751	1·993	1·580 277 449	1,476,193
1·944	1·509 437 034	1,416,931	1·994	1·581 753 642	1,477,431
1·945	1·510 853 965	1,418,113	1·995	1·583 231 073	1,478,670
1·946	1·512 272 078	1,419,296	1·996	1·584 709 743	1,479,912
1·947	1·513 691 374	1,420,480	1·997	1·586 189 655	1,481,156
1·948	1·515 111 854	1,421,665	1·998	1·587 670 811	1,482,400
1·949	1·516 533 519	1,422,851	1·999	1·589 153 211	1,483,644
1·950	1·517 956 370	1,424,038	2·000	1·590 636 855	1,484,890

x	I_1x	Difference	x	I_1x	Difference
2·000	1·590 636 855	1,484,890	2·050	1·666 433 299	1,548,758
2·001	1·592 121 745	1,486,137	2·051	1·667 982 057	1,550,067
2·002	1·593 607 882	1,487,386	2·052	1·669 532 124	1,551,380
2·003	1·595 095 268	1,488,636	2·053	1·671 083 504	1,552,688
2·004	1·596 583 904	1,489,887	2·054	1·672 636 192	1,554,004
2·005	1·598 073 791	1,491,139	2·055	1·674 190 196	1,555,316
2·006	1·599 564 930	1,492,393	2·056	1·675 745 512	1,556,631
2·007	1·601 057 323	1,493,647	2·057	1·677 302 143	1,557,949
2·008	1·602 550 970	1,494,902	2·058	1·678 860 092	1,559,266
2·009	1·604 045 872	1,496,161	2·059	1·680 419 358	1,560,586
2·010	1·605 542 033	1,497,418	2·060	1·681 979 944	1,561,906
2·011	1·607 039 451	1,498,678	2·061	1·683 541 850	1,563,227
2·012	1·608 538 129	1,499,938	2·062	1·685 105 077	1,564,551
2·013	1·610 038 067	1,501,201	2·063	1·686 669 628	1,565,875
2·014	1·611 539 268	1,502,463	2·064	1·688 235 503	1,567,201
2·015	1·613 041 731	1,503,728	2·065	1·689 802 704	1,568,527
2·016	1·614 545 459	1,504,994	2·066	1·691 371 231	1,569,856
2·017	1·616 050 453	1,506,261	2·067	1·692 941 087	1,571,184
2·018	1·617 556 714	1,507,528	2·068	1·694 512 271	1,572,515
2·019	1·619 064 242	1,508,797	2·069	1·696 084 786	1,573,849
2·020	1·620 573 039	1,510,068	2·070	1·697 658 635	1,575,179
2·021	1·622 083 107	1,511,340	2·071	1·699 233 814	1,576,516
2·022	1·623 594 447	1,512,613	2·072	1·700 810 330	1,577,851
2·023	1·625 107 060	1,513,887	2·073	1·702 388 181	1,579,188
2·024	1·626 620 947	1,515,162	2·074	1·703 967 369	1,580,527
2·025	1·628 136 109	1,516,440	2·075	1·705 547 896	1,581,866
2·026	1·629 652 549	1,517,717	2·076	1·707 129 762	1,583,207
2·027	1·631 170 266	1,518,995	2·077	1·708 712 969	1,584,549
2·028	1·632 689 261	1,520,276	2·078	1·710 297 518	1,585,892
2·029	1·634 209 537	1,521,558	2·079	1·711 883 410	1,587,238
2·030	1·635 731 095	1,522,841	2·080	1·713 470 648	1,588,584
2·031	1·637 253 936	1,524,125	2·081	1·715 059 232	1,589,931
2·032	1·638 778 061	1,525,409	2·082	1·716 649 163	1,591,279
2·033	1·640 303 470	1,526,696	2·083	1·718 240 442	1,592,630
2·034	1·641 830 166	1,527,985	2·084	1·719 833 072	1,593,981
2·035	1·643 358 151	1,529,275	2·085	1·721 427 053	1,595,333
2·036	1·644 887 426	1,530,564	2·086	1·723 022 386	1,596,689
2·037	1·646 417 990	1,531,854	2·087	1·724 619 075	1,598,042
2·038	1·647 949 844	1,533,148	2·088	1·726 217 117	1,599,399
2·039	1·649 482 992	1,534,442	2·089	1·727 816 516	1,600,757
2·040	1·651 017 434	1,535,737	2·090	1·729 417 273	1,602,116
2·041	1·652 553 171	1,537,034	2·091	1·731 019 389	1,603,477
2·042	1·654 090 205	1,538,331	2·092	1·732 622 866	1,604,838
2·043	1·655 628 536	1,539,631	2·093	1·734 227 704	1,606,201
2·044	1·657 168 167	1,540,931	2·094	1·735 833 905	1,607,566
2·045	1·658 709 098	1,542,232	2·095	1·737 441 471	1,608,930
2·046	1·660 251 330	1,543,535	2·096	1·739 050 401	1,610,298
2·047	1·661 794 865	1,544,839	2·097	1·740 660 699	1,611,667
2·048	1·663 339 704	1,546,144	2·098	1·742 272 366	1,613,036
2·049	1·664 885 848	1,547,451	2·099	1·743 885 402	1,614,408
2·050	1·666 433 299	1,548,758	2·100	1·745 499 810	1,615,779

x	I_1x	Difference	x	I_1x	Difference
2·100	1·745 499 810	1,615,779	2·150	1·827 997 461	1,686,095
2·101	1·747 115 589	1,617,152	2·151	1·829 683 556	1,687,535
2·102	1·748 732 741	1,618,528	2·152	1·831 371 091	1,688,978
2·103	1·750 351 269	1,619,903	2·153	1·833 060 069	1,690,421
2·104	1·751 971 172	1,621,282	2·154	1·834 750 490	1,691,867
2·105	1·753 592 454	1,622,660	2·155	1·836 442 357	1,693,313
2·106	1·755 215 114	1,624,040	2·156	1·838 135 670	1,694,761
2·107	1·756 839 154	1,625,421	2·157	1·839 830 431	1,696,210
2·108	1·758 464 575	1,626,805	2·158	1·841 526 641	1,697,662
2·109	1·760 091 380	1,628,187	2·159	1·843 224 303	1,699,112
2·110	1·761 719 567	1,629,574	2·160	1·844 923 415	1,700,565
2·111	1·763 349 141	1,630,961	2·161	1·846 623 980	1,702,022
2·112	1·764 980 102	1,632,349	2·162	1·848 326 002	1,703,476
2·113	1·766 612 451	1,633,738	2·163	1·850 029 478	1,704,935
2·114	1·768 246 189	1,635,130	2·164	1·851 734 413	1,706,394
2·115	1·769 881 319	1,636,520	2·165	1·853 440 807	1,707,854
2·116	1·771 517 839	1,637,915	2·166	1·855 148 661	1,709,316
2·117	1·773 155 754	1,639,309	2·167	1·856 857 977	1,710,778
2·118	1·774 795 063	1,640,706	2·168	1·858 568 755	1,712,245
2·119	1·776 435 769	1,642,102	2·169	1·860 281 000	1,713,709
2·120	1·778 077 871	1,643,501	2·170	1·861 994 709	1,715,176
2·121	1·779 721 372	1,644,903	2·171	1·863 709 885	1,716,645
2·122	1·781 366 275	1,646,302	2·172	1·865 426 530	1,718,116
2·123	1·783 012 577	1,647,706	2·173	1·867 144 646	1,719,587
2·124	1·784 660 283	1,649,111	2·174	1·868 864 233	1,721,061
2·125	1·786 309 394	1,650,515	2·175	1·870 585 294	1,722,534
2·126	1·787 959 909	1,651,923	2·176	1·872 307 828	1,724,011
2·127	1·789 611 832	1,653,332	2·177	1·874 031 839	1,725,487
2·128	1·791 265 164	1,654,740	2·178	1·875 757 326	1,726,965
2·129	1·792 919 904	1,656,151	2·179	1·877 484 291	1,728,447
2·130	1·794 576 055	1,657,564	2·180	1·879 212 738	1,729,928
2·131	1·796 233 619	1,658,977	2·181	1·880 942 666	1,731,409
2·132	1·797 892 596	1,660,391	2·182	1·882 674 075	1,732,895
2·133	1·799 552 987	1,661,809	2·183	1·884 406 970	1,734,382
2·134	1·801 214 796	1,663,226	2·184	1·886 141 352	1,735,866
2·135	1·802 878 022	1,664,645	2·185	1·887 877 218	1,737,355
2·136	1·804 542 667	1,666,065	2·186	1·889 614 573	1,738,848
2·137	1·806 208 732	1,667,487	2·187	1·891 353 421	1,740,336
2·138	1·807 876 219	1,668,912	2·188	1·893 093 757	1,741,831
2·139	1·809 545 131	1,670,334	2·189	1·894 835 588	1,743,324
2·140	1·811 215 465	1,671,761	2·190	1·896 578 912	1,744,819
2·141	1·812 887 226	1,673,188	2·191	1·898 323 731	1,746,317
2·142	1·814 560 414	1,674,616	2·192	1·900 070 048	1,747,816
2·143	1·816 235 030	1,676,047	2·193	1·901 817 864	1,749,315
2·144	1·817 911 077	1,677,477	2·194	1·903 567 179	1,750,817
2·145	1·819 588 554	1,678,911	2·195	1·905 317 996	1,752,320
2·146	1·821 267 465	1,680,345	2·196	1·907 070 316	1,753,823
2·147	1·822 947 810	1,681,780	2·197	1·908 824 139	1,755,329
2·148	1·824 629 590	1,683,216	2·198	1·910 579 468	1,756,837
2·149	1·826 312 806	1,684,655	2·199	1·912 336 305	1,758,346
2·150	1·827 997 461	1,686,095	2·200	1·914 094 651	1,759,854

x	I_1x	Difference	x	I_1x	Difference
2·200	1·914 094 651	1,759,854	2·250	2·003 967 457	1,837,218
2·201	1·915 854 505	1,761,367	2·251	2·005 804 675	1,838,803
2·202	1·917 615 872	1,762,879	2·252	2·007 643 478	1,840,390
2·203	1·919 378 751	1,764,393	2·253	2·009 483 868	1,841,978
2·204	1·921 143 144	1,765,910	2·254	2·011 325 846	1,843,568
2·205	1·922 909 054	1,767,427	2·255	2·013 169 414	1,845,159
2·206	1·924 676 481	1,768,945	2·256	2·015 014 573	1,846,751
2·207	1·926 445 426	1,770,466	2·257	2·016 861 324	1,848,346
2·208	1·928 215 892	1,771,987	2 258	2·018 709 670	1,849,942
2·209	1·929 987 879	1,773,509	2·259	2·020 559 612	1,851,539
2·210	1·931 761 388	1,775,034	2·260	2·022 411 151	1,853,137
2·211	1·933 536 422	1,776,561	2·261	2·024 264 288	1,854,738
2·212	1·935 312 983	1,778,088	2·262	2·026 119 026	1,856,340
2·213	1·937 091 071	1,779,616	2·263	2·027 975 366	1,857,943
2·214	1·938 870 687	1,781,147	2·264	2·029 833 309	1,859,547
2·215	1·940 651 834	1,782,678	2·265	2·031 692 856	1,861,154
2·216	1·942 434 512	1,784,210	2·266	2·033 554 010	1,862,762
2·217	1·944 218 722	1,785,747	2·267	2·035 416 772	1,864,372
2·218	1·946 004 469	1,787,283	2·268	2·037 281 144	1,865,983
2·219	1·947 791 752	1,788,820	2·269	2·039 147 127	1,867,595
2·220	1·949 580 572	1,790,359	2·270	2·041 014 722	1,869,208
2·221	1·951 370 931	1,791,899	2·271	2·042 883 930	1,870,824
2·222	1·953 162 830	1,793,441	2·272	2·044 754 754	1,872,442
2·223	1·954 956 271	1,794,985	2·273	2·046 627 196	1,874,061
2·224	1·956 751 256	1,796,530	2·274	2·048 501 257	1,875,681
2·225	1·958 547 786	1,798,077	2·275	2·050 376 938	1,877,302
2·226	1·960 345 863	1,799,623	2·276	2·052 254 240	1,878,925
2·227	1·962 145 486	1,801,173	2·277	2·054 133 165	1,880,549
2·228	1·963 946 659	1,802,724	2·278	2·056 013 714	1,882,176
2·229	1·965 749 383	1,804,277	2·279	2·057 895 890	1,883,805
2·230	1·967 553 660	1,805,830	2·280	2·059 779 695	1,885,434
2·231	1·969 359 490	1,807,385	2·281	2·061 665 129	1,887,064
2·232	1·971 166 875	1,808,943	2·282	2·063 552 193	1,888,697
2·233	1·972 975 818	1,810,501	2·283	2·065 440 890	1,890,332
2·234	1·974 786 319	1,812,060	2·284	2·067 331 222	1,891,967
2·235	1·976 598 379	1,813,621	2·285	2·069 223 189	1,893,604
2·236	1·978 412 000	1,815,184	2·286	2·071 116 793	1,895,242
2·237	1·980 227 184	1,816,748	2·287	2·073 012 035	1,896,883
2·238	1·982 043 932	1,818,314	2·288	2·074 908 918	1,898,525
2·239	1·983 862 246	1,819,881	2·289	2·076 807 443	1,900,168
2·240	1·985 682 127	1,821,448	2·290	2·078 707 611	1,901,813
2·241	1·987 503 575	1,823,020	2·291	2·080 609 424	1,903,461
2·242	1·989 326 595	1,824,592	2·292	2·082 512 885	1,905,109
2·243	1·991 151 187	1,826,165	2·293	2·084 417 994	1,906,757
2·244	1·992 977 352	1,827,739	2·294	2·086 324 751	1,908,409
2·245	1·994 805 091	1,829,315	2·295	2·088 233 160	1,910,062
2·246	1·996 634 406	1,830,891	2·296	2·090 143 222	1,911,715
2·247	1·998 465 297	1,832,472	2·297	2·092 054 937	1,913,372
2·248	2·000 297 769	1,834,053	2·298	2·093 968 309	1,915,030
2·249	2·002 131 822	1,835,635	2·299	2·095 883 339	1,916,689
2·250	2·003 967 457	1,837,218	2·300	2·097 800 028	1,918,349

x	I_1x	Difference	x	I_1x	Difference
2·300	2·097 800 028	1,918,349	2·350	2·195 784 977	2,003,423
2·301	2·099 718 377	1,920,011	2·351	2·197 788 400	2,005,164
2·302	2·101 638 388	1,921,675	2·352	2·199 793 564	2,006,909
2·303	2·103 560 063	1,923,341	2·353	2·201 800 473	2,008,656
2·304	2·105 483 404	1,925,007	2·354	2·203 809 129	2,010,404
2·305	2·107 408 411	1,926,677	2·355	2·205 819 533	2,012,152
2·306	2·109 335 088	1,928,347	2·356	2·207 831 685	2,013,903
2·307	2·111 263 435	1,930,018	2·357	2·209 845 588	2,015,657
2·308	2·113 193 453	1,931,690	2·358	2·211 861 245	2,017,412
2·309	2·115 125 143	1,933,367	2·359	2·213 878 657	2,019,168
2·310	2·117 058 510	1,935,043	2·360	2·215 897 825	2,020,925
2·311	2·118 993 553	1,936,720	2·361	2·217 918 750	2,022,685
2·312	2·120 930 273	1,938,400	2·362	2·219 941 435	2,024,445
2·313	2·122 868 673	1,940,083	2·363	2·221 965 880	2,026,209
2·314	2·124 808 756	1,941,765	2·364	2·223 992 089	2,027,973
2·315	2·126 750 521	1,943,449	2·365	2·226 020 062	2,029,739
2·316	2·128 693 970	1,945,135	2·366	2·228 049 801	2,031,507
2·317	2·130 639 105	1,946,823	2·367	2·230 081 308	2,033,277
2·318	2·132 585 928	1,948,512	2·368	2·232 114 585	2,035,048
2·319	2·134 534 440	1,950,202	2·369	2·234 149 633	2,036,820
2·320	2·136 484 642	1,951,895	2·370	2·236 186 453	2,038,595
2·321	2·138 436 537	1,953,589	2·371	2·238 225 048	2,040,371
2·322	2·140 390 126	1,955,285	2·372	2·240 265 419	2,042,150
2·323	2·142 345 411	1,956,982	2·373	2·242 307 569	2,043,928
2·324	2·144 302 393	1,958,681	2·374	2·244 351 497	2,045,709
2·325	2·146 261 074	1,960,382	2·375	2·246 397 206	2,047,494
2·326	2·148 221 456	1,962,084	2·376	2·248 444 700	2,049,276
2·327	2·150 183 540	1,963,788	2·377	2·250 493 976	2,051,064
2·328	2·152 147 328	1,965,493	2·378	2·252 545 040	2,052,853
2·329	2·154 112 821	1,967,200	2·379	2·254 597 893	2,054,641
2·330	2·156 080 021	1,968,908	2·380	2·256 652 534	2,056,433
2·331	2·158 048 929	1,970,618	2·381	2·258 708 967	2,058,225
2·332	2·160 019 547	1,972,330	2·382	2·260 767 192	2,060,021
2·333	2·161 991 877	1,974,044	2·383	2·262 827 213	2,061,816
2·334	2·163 965 921	1,975,759	2·384	2·264 889 029	2,063,616
2·335	2·165 941 680	1,977,475	2·385	2·266 952 645	2,065,415
2·336	2·167 919 155	1,979,194	2·386	2·269 018 060	2,067,216
2·337	2·169 898 349	1,980,914	2·387	2·271 085 276	2,069,020
2·338	2·171 879 263	1,982,636	2·388	2·273 154 296	2,070,825
2·339	2·173 861 899	1,984,358	2·389	2·275 225 121	2,072,632
2·340	2·175 846 257	1,986,083	2·390	2·277 297 753	2,074,439
2·341	2·177 832 340	1,987,810	2·391	2·279 372 192	2,076,250
2·342	2·179 820 150	1,989,538	2·392	2·281 448 442	2,078,063
2·343	2·181 809 688	1,991,269	2·393	2·283 526 505	2,079,876
2·344	2·183 800 957	1,992,998	2·394	2·285 606 381	2,081,690
2·345	2·185 793 955	1,994,731	2·395	2·287 688 071	2,083,508
2·346	2·187 788 686	1,996,467	2·396	2·289 771 579	2,085,326
2·347	2·189 785 153	1,998,204	2·397	2·291 856 905	2,087,146
2·348	2·191 783 357	1,999,939	2·398	2·293 944 051	2,088,969
2·349	2·193 783 296	2,001,681	2·399	2·296 033 020	2,090,793
2·350	2·195 784 977	2,003,423	2·400	2·298 123 813	2,092,618

x	I_1x	Difference	x	I_1x	Difference
2·400	2·298 123 813	2,092,618	2·450	2·405 027 363	2,186,129
2·401	2·300 216 431	2,094,446	2·451	2·407 213 492	2,188,045
2·402	2·302 310 877	2,096,274	2·452	2·409 401 537	2,189,962
2·403	2·304 407 151	2,098,104	2·453	2·411 591 499	2,191,881
2·404	2·306 505 255	2,099,938	2·454	2·413 783 380	2,193,803
2·405	2·308 605 193	2,101,772	2·455	2·415 977 183	2,195,726
2·406	2·310 706 965	2,103,608	2·456	2·418 172 909	2,197,649
2·407	2·312 810 573	2,105,445	2·457	2·420 370 558	2,199,576
2·408	2·314 916 018	2,107,285	2·458	2·422 570 134	2,201,505
2·409	2·317 023 303	2,109,126	2·459	2·424 771 639	2,203,436
2·410	2·319 132 429	2,110,969	2·460	2·426 975 075	2,205,367
2·411	2·321 243 398	2,112,814	2·461	2·429 180 442	2,207,301
2·412	2·323 356 212	2,114,660	2·462	2·431 387 743	2,209,236
2·413	2·325 470 872	2,116,508	2·463	2·433 596 979	2,211,173
2·414	2·327 587 380	2,118,357	2·464	2·435 808 152	2,213,112
2·415	2·329 705 737	2,120,209	2·465	2·438 021 264	2,215,055
2·416	2·331 825 946	2,122,063	2·466	2·440 236 319	2,216,997
2·417	2·333 948 009	2,123,919	2·467	2·442 453 316	2,218,941
2·418	2·336 071 928	2,125,775	2·468	2·444 672 257	2,220,887
2·419	2·338 197 703	2,127,633	2·469	2·446 893 144	2,222,837
2·420	2·340 325 336	2,129,493	2·470	2·449 115 981	2,224,786
2·421	2·342 454 829	2,131,357	2·471	2·451 340 767	2,226,738
2·422	2·344 586 186	2,133,220	2·472	2·453 567 505	2,228,695
2·423	2·346 719 406	2,135,086	2·473	2·455 796 200	2,230,648
2·424	2·348 854 492	2,136,953	2·474	2·458 026 848	2,232,607
2·425	2·350 991 445	2,138,822	2·475	2·460 259 455	2,234,564
2·426	2·353 130 267	2,140,692	2·476	2·462 494 019	2,236,526
2·427	2·355 270 959	2,142,565	2·477	2·464 730 545	2,238,491
2·428	2·357 413 524	2,144,440	2·478	2·466 969 036	2,240,453
2·429	2·359 557 964	2,146,317	2·479	2·469 209 489	2,242,423
2·430	2·361 704 281	2,148,194	2·480	2·471 451 912	2,244,390
2·431	2·363 852 475	2,150,074	2·481	2·473 696 302	2,246,360
2·432	2·366 002 549	2,151,956	2·482	2·475 942 662	2,248,333
2·433	2·368 154 505	2,153,840	2·483	2·478 190 995	2,250,309
2·434	2·370 308 345	2,155,725	2·484	2·480 441 304	2,252,284
2·435	2·372 464 070	2,157,611	2·485	2·482 693 588	2,254,260
2·436	2·374 621 681	2,159,500	2·486	2·484 947 848	2,256,241
2·437	2·376 781 181	2,161,390	2·487	2·487 204 089	2,258,224
2·438	2·378 942 571	2,163,282	2·488	2·489 462 313	2,260,208
2·439	2·381 105 853	2,165,176	2·489	2·491 722 521	2,262,191
2·440	2·383 271 029	2,167,073	2·490	2·493 984 712	2,264,179
2·441	2·385 438 102	2,168,971	2·491	2·496 248 891	2,266,168
2·442	2·387 607 073	2,170,869	2·492	2·498 515 059	2,268,160
2·443	2·389 777 942	2,172,769	2·493	2·500 783 219	2,270,153
2·444	2·391 950 711	2,174,674	2·494	2·503 053 372	2,272,149
2·445	2·394 125 385	2,176,580	2·495	2·505 325 521	2,274,144
2·446	2·396 301 965	2,178,484	2·496	2·507 599 665	2,276,142
2·447	2·398 480 449	2,180,393	9·497	2·509 875 807	2,278,143
2·448	2·400 660 842	2,182,304	2·498	2·512 153 950	2,280,146
2·449	2·402 843 146	2,184,217	2·499	2·514 434 096	2,282,150
2·450	2·405 027 363	2,186,129	2·500	2·516 716 246	2,284,156

x	I_1x	Difference	x	I_1x	Difference
2·500	2·516 716 246	2,284,156	2·550	2·633 421 351	2,386,908
2·501	2·519 000 402	2,286,164	2·551	2·635 808 259	2,389,012
2·502	2·521 286 566	2,288,174	2·552	2·638 197 271	2,391,123
2·503	2·523 574 740	2,290,185	2·553	2·640 588 394	2,393,228
2·504	2·525 864 925	2,292,199	2·554	2·642 981 622	2,395,339
2·505	2·528 157 124	2,294,215	2·555	2·645 376 961	2,397,452
2·506	2·530 451 339	2,296,233	2·556	2·647 774 413	2,399,568
2·507	2·532 747 572	2,298,252	2·557	2·650 173 981	2,401,683
2·508	2·535 045 824	2,300,274	2·558	2·652 575 664	2,403,801
2 509	2·537 346 098	2,302,296	2·559	2·654 979 465	2,405,924
2·510	2·539 648 394	2,304,321	2·560	2·657 385 389	2,408,047
2·511	2·541 952 715	2,306,349	2·561	2·659 793 436	2,410,169
2·512	2·544 259 064	2,308,378	2·562	2·662 203 605	2,412,297
2·513	2·546 567 442	2,310,408	2·563	2·664 615 902	2,414,426
2·514	2·548 877 850	2,312,441	2·564	2·667 030 328	2,416,555
2·515	2·551 190 291	2,314,476	2·565	2·669 446 883	2,418,689
2·516	2·553 504 767	2,316,512	2·566	2·671 865 572	2,420,824
2·517	2·555 821 279	2,318,551	2·567	2·674 286 396	2,422,959
2·518	2·558 139 830	2,320,591	2·568	2·676 709 355	2,425,099
2·519	2·560 460 421	2,322,634	2·569	2·679 134 454	2,427,240
2·520	2·562 783 055	2,324,678	2·570	2·681 561 694	2,429,382
2·521	2·565 107 733	2,326,724	2·571	2·683 991 076	2,431,526
2·522	2·567 434 457	2,328,772	2·572	2·686 422 602	2,433,673
2·523	2·569 763 229	2,330,822	2·573	2·688 856 275	2,435,823
2·524	2·572 094 051	2,332,875	2·574	2·691 292 098	2,437,972
2·525	2·574 426 926	2,334,927	2·575	2·693 730 070	2,440,127
2·526	2·576 761 853	2,336,985	2·576	2·696 170 197	2,442,280
2·527	2·579 098 838	2,339,041	2·577	2·698 612 477	2,444,438
2·528	2·581 437 879	2,341,101	2·578	2·701 056 915	2,446,595
2·529	2·583 778 980	2,343,163	2·579	2·703 503 510	2,448,759
2·530	2·586 122 143	2,345,227	2·580	2·705 952 269	2,450,920
2·531	2·588 467 370	2,347,292	2·581	2·708 403 189	2,453,084
2·532	2·590 814 662	2,349,360	2·582	2·710 856 273	2,455,253
2·533	2·593 164 022	2,351,429	2·583	2·713 311 526	2,457,420
2·534	2·595 515 451	2,353,499	2·584	2·715 768 946	2,459,592
2·535	2·597 868 950	2,355,575	2·585	2·718 228 538	2,461,765
2·536	2·600 224 525	2,357,648	2·586	2·720 690 303	2,463,941
2·537	2·602 582 173	2,359,727	2·587	2·723 154 244	2,466,118
2·538	2·604 941 900	2,361,805	2·588	2·725 620 362	2,468,297
2·539	2·607 303 705	2,363,887	2·589	2·728 088 659	2,470,478
2·540	2·609 667 592	2,365,969	2·590	2·730 559 137	2,472,661
2·541	2·612 033 561	2,368,055	2·591	2·733 031 798	2,474,846
2·542	2·614 401 616	2,370,142	2·592	2·735 506 644	2,477,035
2 543	2·616 771 758	2,372,231	2·593	2·737 983 679	2,479,224
2·544	2·619 143 989	2,374,321	2·594	2·740 462 903	2,481,415
2·545	2·621 518 310	2,376,414	2·595	2·742 944 318	2,483,609
2·546	2·623 894 724	2,378,508	2·596	2·745 427 927	2,485,805
2·547	2·626 273 232	2,380,609	2·597	2·747 913 732	2,488,002
2·548	2·628 653 841	2,382,705	2·598	2·750 401 734	2,490,202
2·549	2·631 036 546	2,384,805	2·599	2·752 891 936	2,492,405
2·550	2·633 421 351	2,386,908	2·600	2·755 384 341	2,494,607

x	I_1x	Difference	x	I_1x	Difference
2·600	2·755 384 341	2,494,607	2·650	2·882 858 180	2,607,486
2·601	2·757 878 948	2,496,814	2·651	2·885 465 666	2,609,798
2·602	2·760 375 762	2,499,022	2·652	2·888 075 464	2,612,112
2·603	2·762 874 784	2,501,233	2·653	2·890 687 576	2,614,428
2·604	2·765 376 017	2,503,445	2·654	2·893 302 004	2,616,746
2·605	2·767 879 462	2,505,659	2·655	2·895 918 750	2,619,069
2·606	2·770 385 121	2,507,874	2·656	2·898 537 819	2,621,390
2·607	2·772 892 995	2,510,095	2·657	2·901 159 209	2,623,716
2·608	2·775 403 090	2,512,314	2·658	2·903 782 925	2,626,042
2·609	2·777 915 404	2,514,537	2·659	2·906 408 967	2,628,373
2·610	2·780 429 941	2,516,761	2·660	2·909 037 340	2,630,703
2·611	2·782 946 702	2,518,989	2·661	2·911 668 043	2,633,039
2·612	2·785 465 691	2,521,217	2·662	2·914 301 082	2,635,373
2·613	2·787 986 908	2,523,449	2·663	2·916 936 455	2,637,712
2·614	2·790 510 357	2,525,681	2·664	2·919 574 167	2,640,053
2·615	2·793 036 038	2,527,916	2·665	2·922 214 220	2,642,395
2·616	2·795 563 954	2,530,156	2·666	2·924 856 615	2,644,739
2·617	2·798 094 110	2,532,393	2·667	2·927 501 354	2,647,086
2·618	2·800 626 503	2,534,634	2·668	2·930 148 440	2,649,438
2·619	2·803 161 137	2,536,880	2·669	2·932 797 878	2,651,787
2·620	2·805 698 017	2,539,124	2·670	2·935 449 665	2,654,139
2·621	2·808 237 141	2,541,372	2·671	2·938 103 804	2,656,497
2·622	2·810 778 513	2,543,622	2·672	2·940 760 301	2,658,855
2·623	2·813 322 135	2,545,874	2·673	2·943 419 156	2,661,215
2·624	2·815 868 009	2,548,129	2·674	2·946 080 371	2,663,577
2·625	2·818 416 138	2,550,384	2·675	2·948 743 948	2,665,941
2·626	2·820 966 522	2,552,643	2·676	2·951 409 889	2,668,310
2·627	2·823 519 165	2,554,903	2·677	2·954 078 199	2,670,678
2·628	2·826 074 068	2,557,166	2·678	2·956 748 877	2,673,050
2·629	2·828 631 234	2,559,432	2·679	2·959 421 927	2,675,422
2·630	2·831 190 666	2,561,698	2·680	2·962 097 349	2,677,798
2·631	2·833 752 364	2,563,967	2·681	2·964 775 147	2,680,177
2·632	2 836 316 331	2,566,239	2·682	2·967 455 324	2,682,557
2·633	2·838 882 570	2,568,512	2·683	2·970 137 881	2,684,940
2·634	2·841 451 082	2,570,787	2·684	2·972 822 821	2,687,324
2·635	2·844 021 869	2,573,063	2·685	2·975 510 145	2,689,711
2·636	2·846 594 932	2,575,344	2·686	2·978 199 856	2,692,100
2·637	2·849 170 276	2,577,627	2·687	2·980 891 956	2,694,490
2·638	2·851 747 903	2,579,910	2·688	2·983 586 446	2,696,885
2·639	2·854 327 813	2,582,196	2·689	2·986 283 331	2,699,282
2·640	2·856 910 009	2,584,484	2·690	2·988 982 613	2,701,679
2·641	2·859 494 493	2,586,775	2·691	2·991 684 292	2,704,080
2·642	2·862 081 268	2,589,067	2·692	2·994 388 372	2,706,482
2·643	2·864 670 335	2,591,362	2·693	2·997 094 854	2,708,887
2·644	2·867 261 697	2,593,659	2·694	2·999 803 741	2,711,294
2·645	2·869 855 356	2 595,958	2·695	3·002 515 035	2,713,704
2·646	2·872 451 314	2,598,260	2·696	3·005 228 739	2,716,115
2·647	2·875 049 574	2,600,562	2·697	3·007 944 854	2,718,529
2·648	2·877 650 136	2,602,868	2·698	3·010 663 383	2,720,947
2·649	2·880 253 004	2,605,176	2·699	3·013 384 330	2,723,364
2·650	2·882 858 180	2,607,486	2·700	3·016 107 694	2,725,784

x	I_1x	Difference	x	I_1x	Difference
2·700	3·016 107 694	2,725,784	2·750	3·155 410 139	2,849,759
2·701	3·018 833 478	2,728,207	2·751	3·158 259 898	2,852,299
2·702	3·021 561 685	2,730,634	2·752	3·161 112 197	2,854,841
2·703	3·024 292 319	2,733,061	2·753	3·163 967 038	2,857,385
2·704	3·027 025 380	2,735,490	2·754	3·166 824 423	2,859,932
2·705	3·029 760 870	2,737,923	2·755	3·169 684 355	2,862,479
2·706	3·032 498 793	2,740,356	2·756	3·172 546 834	2,865,031
2·707	3·035 239 149	2,742,794	2·757	3·175 411 865	2,867,585
2·708	3·037 981 943	2,745,232	2·758	3·178 279 450	2,870,141
2·709	3·040 727 175	2,747,675	2·759	3·181 149 591	2,872,699
2·710	3·043 474 850	2,750,118	2·760	3·184 022 290	2,875,259
2·711	3·046 224 968	2,752,562	2·761	3·186 897 549	2,877,823
2·712	3·048 977 530	2,755,011	2·762	3·189 775 372	2,880,388
2·713	3·051 732 541	2,757,462	2·763	3·192 655 760	2,882,956
2·714	3·054 490 003	2,759,914	2·764	3·195 538 716	2,885,526
2·715	3·057 249 917	2,762,370	2·765	3·198 424 242	2,888,099
2·716	3·060 012 287	2,764,827	2·766	3·201 312 341	2,890,674
2·717	3·062 777 114	2,767,286	2·767	3·204 203 015	2,893,252
2·718	3·065 544 400	2,769,748	2·768	3·207 096 267	2,895,832
2·719	3·068 314 148	2,772,214	2·769	3·209 992 099	2,898,414
2·720	3·071 086 362	2,774,679	2·770	3·212 890 513	2,900,999
2·721	3·073 861 041	2,777,147	2·771	3·215 791 512	2,903,586
2·722	3·076 638 188	2,779,619	2·772	3·218 695 098	2,906,177
2·723	3·079 417 807	2,782,093	2·773	3·221 601 275	2,908,768
2·724	3·082 199 900	2,784,569	2·774	3·224 510 043	2,911,362
2·725	3·084 984 469	2,787,045	2·775	3·227 421 405	2,913,959
2·726	3·087 771 514	2,789,527	2·776	3·230 335 364	2,916,559
2·727	3·090 561 041	2,792,010	2·777	3·233 251 923	2,919,161
2·728	3·093 353 051	2,794,495	2·778	3·236 171 084	2,921,765
2·729	3·096 147 546	2,796,982	2·779	3·239 092 849	2,924,370
2·730	3·098 944 528	2,799,472	2·780	3·242 017 219	2,926,980
2·731	3·101 744 000	2,801,964	2·781	3·244 944 199	2,929,593
2·732	3·104 545 964	2,804,459	2·782	3·247 873 792	2,932,206
2·733	3·107 350 423	2,806,956	2·783	3·250 805 998	2,934,822
2·734	3·110 157 379	2,809,454	2·784	3·253 740 820	2,937,441
2·735	3·112 966 833	2,811,956	2·785	3·256 678 261	2,940,063
2·736	3·115 778 789	2,814,459	2·786	3·259 618 324	2,942,687
2·737	3·118 593 248	2,816,966	2·787	3·262 561 011	2,945,312
2·738	3·121 410 214	2,819,474	2·788	3·265 506 323	2,947,941
2·739	3·124 229 688	2,821,985	2·789	3·268 454 264	2,950,573
2·740	3·127 051 673	2,824,498	2·790	3·271 404 837	2,953,207
2·741	3·129 876 171	2,827,014	2·791	3·274 358 044	2,955,843
2·742	3·132 703 185	2,829,532	2·792	3·277 313 887	2,958,481
2·743	3·135 532 717	2,832,052	2·793	3·280 272 368	2,961,121
2·744	3·138 364 769	2,834,574	2·794	3·283 233 489	2,963,766
2·745	3·141 199 343	2,837,100	2·795	3·286 197 255	2,966,411
2·746	3·144 036 443	2,839,628	2·796	3·289 163 666	2,969,060
2·747	3·146 876 071	2,842,156	2·797	3·292 132 726	2,971,712
2·748	3·149 718 227	2,844,688	2·798	3·295 104 438	2,974,365
2·749	3·152 562 915	2,847,224	2·799	3·298 078 803	2,977,020
2·750	3·155 410 139	2,849,759	2·800	3·301 055 823	2,979,678

x	I_1x	Difference	x	I_1x	Difference
2·800	3·301 055 823	2,979,678	2·850	3·453 348 735	3,115,822
2·801	3·304 035 501	2,982,339	2·851	3·456 464 557	3,118,610
2·802	3·307 017 840	2,985,004	2·852	3·459 583 167	3,121,400
2·803	3·310 002 844	2,987,670	2·853	3·462 704 567	3,124,194
2·804	3·312 990 514	2,990,337	2·854	3·465 828 761	3,126,990
2·805	3·315 980 851	2,993,008	2·855	3·468 955 751	3,129,790
2·806	3·318 973 859	2,995,681	2·856	3·472 085 541	3,132,590
2·807	3·321 969 540	2,998,358	2·857	3·475 218 131	3,135,394
2·808	3·324 967 898	3,001,036	2·858	3·478 353 525	3,138,201
2·809	3·327 968 934	3,003,717	2·859	3·481 491 726	3,141,011
2·810	3·330 972 651	3,006,400	2·860	3·484 632 737	3,143,823
2·811	3·333 979 051	3,009,086	2·861	3·487 776 560	3,146,638
2·812	3·336 988 137	3,011,776	2·862	3·490 923 198	3,149,454
2·813	3·339 999 913	3,014,465	2·863	3·494 072 652	3,152,273
2·814	3·343 014 378	3,017,158	2·864	3·497 224 925	3,155,096
2·815	3·346 031 536	3,019,854	2·865	3·500 380 021	3,157,922
2·816	3·349 051 390	3,022,554	2·866	3·503 537 943	3,160,749
2·817	3·352 073 944	3,025,256	2·867	3·506 698 692	3,163,580
2·818	3·355 099 200	3,027,957	2·868	3·509 862 272	3,166,413
2·819	3·358 127 157	3,030,664	2·869	3·513 028 685	3,169,248
2·820	3·361 157 821	3,033,374	2·870	3·516 197 933	3,172,086
2·821	3·364 191 195	3,036,083	2·871	3·519 370 019	3,174,928
2·822	3·367 227 278	3,038,799	2·872	3·522 544 947	3,177,772
2·823	3·370 266 077	3,041,514	2·873	3·525 722 719	3,180,618
2·824	3·373 307 591	3,044,232	2·874	3·528 903 337	3,183,466
2·825	3·376 351 823	3,046,954	2·875	3·532 086 803	3,186,317
2·826	3·379 398 777	3,049,678	2·876	3·535 273 120	3,189,172
2·827	3·382 448 455	3,052,405	2·877	3·538 462 292	3,192,030
2·828	3·385 500 860	3,055,133	2·878	3·541 654 322	3,194,889
2·829	3·388 555 993	3,057,864	2·879	3·544 849 211	3,197,751
2·830	3·391 613 857	3,060,600	2·880	3·548 046 962	3,200,617
2·831	3·394 674 457	3,063,336	2·881	3·551 247 579	3,203,484
2·832	3·397 737 793	3,066,075	2·882	3·554 451 063	3,206,355
2·833	3·400 803 868	3,068,817	2·883	3·557 657 418	3,209,226
2·834	3·403 872 685	3,071,561	2·884	3·560 866 644	3,212,103
2·835	3·406 944 246	3,074,307	2·885	3·564 078 747	3,214,982
2·836	3·410 018 553	3,077,057	2·886	3·567 293 729	3,217,862
2·837	3·413 095 610	3,079,810	2·887	3·570 511 591	3,220,747
2·838	3·416 175 420	3,082,565	2·888	3·573 732 338	3,223,632
2·839	3·419 257 985	3,085,321	2·889	3·576 955 970	3,226,522
2·840	3·422 343 306	3,088,081	2·890	3·580 182 492	3,229,413
2·841	3·425 431 387	3,090,843	2·891	3·583 411 905	3,232,308
2·842	3·428 522 230	3,093,609	2·892	3·586 644 213	3,235,206
2·843	3·431 615 839	3,096,376	2·893	3·589 879 419	3,238,106
2·844	3·434 712 215	3,099,146	2·894	3·593 117 525	3,241,009
2·845	3·437 811 361	3,101,918	2·895	3·596 358 534	3,243,914
2·846	3·440 913 279	3,104,695	2·896	3·599 602 448	3,246,822
2·847	3·444 017 974	3,107,473	2·897	3·602 849 270	3,249,733
2·848	3·447 125 447	3,110,252	2·898	3·606 099 003	3,252,646
2·849	3·450 235 699	3,113,036	2·899	3·609 351 649	3,255,563
2·850	3·453 348 735	3,115,822	2·900	3·612 607 212	3,258,482

x	I_1x	Difference	x	I_1x	Difference
2·900	3·612 607 212	3,258,482	2·950	3·779 164 648	3,407,969
2·901	3·615 865 694	3,261,404	2·951	3·782 572 617	3,411,031
2·902	3·619 127 098	3,264,328	2·952	3·785 983 648	3,414,095
2·903	3·622 391 426	3,267,255	2·953	3·789 397 743	3,417,161
2·904	3·625 658 681	3,270,186	2·954	3·792 814 904	3,420,232
2·905	3·628 928 867	3,273,119	2·955	3·796 235 136	3,423,306
2·906	3·632 201 986	3,276,054	2·956	3·799 658 442	3,426,382
2·907	3·635 478 040	3,278,992	2·957	3·803 084 824	3,429,460
2·908	3·638 757 032	3,281,932	2·958	3·806 514 284	3,432,541
2·909	3·642 038 964	3,284,876	2·959	3·809 946 825	3,435,627
2·910	3·645 323 840	3,287,823	2·960	3·813 382 452	3,438,714
2·911	3·648 611 663	3,290,773	2·961	3·816 821 166	3,441,803
2·912	3·651 902 436	3,293,725	2·962	3·820 262 969	3,444,897
2·913	3·655 196 161	3,296,679	2·963	3·823 707 866	3,447,994
2·914	3·658 492 840	3,299,637	2·964	3·827 155 860	3,451,092
2·915	3·661 792 477	3,302,597	2·965	3·830 606 952	3,454,194
2·916	3·665 095 074	3,305,560	2·966	3·834 061 146	3,457,298
2·917	3·668 400 634	3,308,526	2·967	3·837 518 444	3,460,407
2·918	3·671 709 160	3,311,494	2·968	3·840 978 851	3,463,517
2·919	3·675 020 654	3,314,466	2·969	3·844 442 368	3,466,631
2·920	3·678 335 120	3,317,440	2·970	3·847 908 999	3,469,747
2·921	3·681 652 560	3,320,417	2·971	3·851 378 746	3,472,866
2·922	3·684 972 977	3,323,396	2·972	3·854 851 612	3,475,988
2·923	3·688 296 373	3,326,379	2·973	3·858 327 600	3,479,114
2·924	3·691 622 752	3,329,365	2·974	3·861 806 714	3,482,242
2·925	3·694 952 117	3,332,353	2·975	3·865 288 956	3,485,372
2·926	3·698 284 470	3,335,343	2·976	3·868 774 328	3,488,506
2·927	3·701 619 813	3,338,336	2·977	3·872 262 834	3,491,643
2·928	3·704 958 149	3,341,333	2·978	3·875 754 477	3,494,784
2·929	3·708 299 482	3,344,332	2·979	3·879 249 261	3,497,927
2·930	3·711 643 814	3,347,335	2·980	3·882 747 188	3,501,071
2·931	3·714 991 149	3,350,339	2·981	3·886 248 259	3,504,220
2·932	3·718 341 488	3,353,347	2·982	3·889 752 479	3,507,372
2·933	3·721 694 835	3,356,359	2·983	3·893 259 851	3,510,526
2·934	3·725 051 194	3,359,371	2·984	3·896 770 377	3,513,683
2·935	3·728 410 565	3,362,387	2·985	3·900 284 060	3,516,844
2·936	3·731 772 952	3,365,405	2·986	3·903 800 904	3,520,007
2·937	3·735 138 357	3,368,428	2·987	3·907 320 911	3,523,174
2·938	3·738 506 785	3,371,452	2·988	3·910 844 085	3,526,343
2·939	2·741 878 237	3,374,481	2·989	3·914 370 428	3,529,515
2·940	3·745 252 718	3,377,510	2·990	3·917 899 943	3,532,690
2·941	3·748 630 228	3,380,543	2·991	3·921 432 633	3,535,868
2·942	3·752 010 771	3,383,580	2·992	3·924 968 501	3,539,049
2·943	3·755 394 351	3,386,618	2·993	3·928 507 550	3,542,234
2·944	3·758 780 969	3,389,659	2·994	3·932 049 784	3,545,420
2·945	3·762 170 628	3,392,703	2·995	3·935 595 204	3,548,611
2·946	3·765 563 331	3,395,752	2·996	3·939 143 815	3,551,804
2·947	3·768 959 083	3,398,801	2·997	3·942 695 619	3,554,999
2·948	3·772 357 884	3,401,854	2·998	3·946 250 618	3,558,199
2·949	3·775 759 738	3,404,910	2·999	3·949 808 817	3,561,400
2·950	3·779 164 648	3,407,969	3·000	3·953 370 217	3,564,606

x	I_1x	Difference	x	I_1x	Difference
3·000	3·953 370 217	3,564,606	3·050	4·135 589 648	3,728,731
3·001	3·956 934 823	3,567,813	3·051	4·139 318 379	3,732,091
3·002	3·960 502 636	3,571,025	3·052	4·143 050 470	3,735,457
3·003	3·964 073 661	3,574,238	3·053	4·146 785 927	3,738,824
3·004	3·967 647 899	3,577,455	3·054	4·150 524 751	3,742,195
3·005	3·971 225 354	3,580,676	3·055	4·154 266 946	3,745,569
3·006	3·974 806 030	3,583,898	3·056	4·158 012 515	3,748,946
3·007	3·978 389 928	3,587,123	3·057	4·161 761 461	3,752,328
3·008	3·981 977 051	3,590,354	3·058	4·165 513 789	3,755,709
3·009	3·985 567 405	3,593,586	3·059	4·169 269 498	3,759,096
3·010	3·989 160 991	3,596,820	3·060	4·173 028 594	3,762,486
3·011	3·992 757 811	3,600,058	3·061	4·176 791 080	3,765,879
3·012	3·996 357 869	3,603,300	3·062	4·180 556 959	3,769,275
3·013	3·999 961 169	3,606,544	3·063	4·184 326 234	3,772,674
3·014	4·003 567 713	3,609,791	3·064	4·188 098 908	3,776,075
3·015	4·007 177 504	3,613,041	3·065	4·191 874 983	3,779,481
3·016	4·010 790 545	3,616,294	3·066	4·195 654 464	3,782,891
3·017	4·014 406 839	3,619,550	3·067	4·199 437 355	3,786,303
3·018	4·018 026 389	3,622,810	3·068	4·203 223 658	3,789,717
3·019	4·021 649 199	3,626,072	3·069	4·207 013 375	3,793,135
3·020	4·025 275 271	3,629,337	3·070	4·210 806 510	3,796,557
3·021	4·028 904 608	3,632,606	3·071	4·214 603 067	3,799,982
3·022	4·032 537 214	3,635,877	3·072	4·218 403 049	3,803,410
3·023	4·036 173 091	3,639,152	3·073	4·222 206 459	3,806,841
3·024	4·039 812 243	3,642,430	3·074	4·226 013 300	3,810,275
3·025	4·043 454 673	3,645,710	3·075	4·229 823 575	3,813,713
3·026	4·047 100 383	3,648,994	3·076	4·233 637 288	3,817,153
3·027	4·050 749 377	3,652,281	3·077	4·237 454 441	3,820,597
3·028	4·054 401 658	3,655,572	3·078	4·241 275 038	3,824,044
3·029	4·058 057 230	3,658,864	3·079	4·245 099 082	3,827,495
3·030	4·061 716 094	3,662,159	3·080	4·248 926 577	3,830,949
3·031	4·065 378 253	3,665,458	3·081	4·252 757 526	3,834,404
3·032	4·069 043 711	3,668,761	3·082	4·256 591 930	3,837,865
3·033	4·072 712 472	3,672,067	3·083	4·260 429 795	3,841,329
3·034	4·076 384 539	3,675,375	3·084	4·264 271 124	3,844,795
3·035	4·080 059 914	3,678,685	3·085	4·268 115 919	3,848,264
3·036	4·083 738 599	3,682,001	3·086	4·271 964 183	3,851,737
3·037	4·087 420 600	3,685,319	3·087	4·275 815 920	3,855,214
3·038	4·091 105 919	3,688,639	3·088	4·279 671 134	3,858,693
3·039	4·094 794 558	3,691,962	3·089	4·283 529 827	3,862,176
3·040	4·098 486 520	3,695,290	3·090	4·287 392 003	3,865,662
3·041	4·102 181 810	3,698,620	3·091	4·291 257 665	3,869,151
3·042	4·105 880 430	3,701,954	3·092	4·295 126 816	3,872,643
3·043	4·109 582 384	3,705,289	3·093	4·298 999 459	3,876,139
3·044	4·113 287 673	3,708,629	3·094	4·302 875 598	3,879,639
3·045	4·116 996 302	3,711,972	3·095	4·306 755 237	3,883,140
3·046	4·120 708 274	3,715,317	3·096	4·310 638 377	3,886,646
3·047	4·124 423 591	3,718,665	3·097	4·314 525 023	3,890,155
3·048	4·128 142 256	3,722,018	3·098	4·318 415 178	3,893,666
3·049	4·131 864 274	3,725,374	3·099	4·322 308 844	3,897,183
3·050	4·135 589 648	3,728,731	3·100	4·326 206 027	3,900,702

x	I_1x	Difference	x	I_1x	Difference
3·100	4·326 206 027	3,900,702	3·150	4·525 620 649	4,080,888
3·101	4·330 106 729	3,904,223	3·151	4·529 701 537	4,084,579
3·102	4·334 010 952	3,907,748	3·152	4·533 786 116	4,088,272
3·103	4·337 918 700	3,911,277	3·153	4·537 874 388	4,091,970
3·104	4·341 829 977	3,914,809	3·154	4·541 966 358	4,095,671
3·105	4·345 744 786	3,918,344	3·155	4·546 062 029	4,099,374
3·106	4·349 663 130	3,921,882	3·156	4·550 161 403	4,103,082
3·107	4·353 585 012	3,925,423	3·157	4·554 264 485	4,106,793
3·108	4·357 510 435	3,928,968	3·158	4·558 371 278	4,110,506
3·109	4·361 439 403	3,932,518	3·159	4·562 481 784	4,114,225
3·110	4·365 371 921	3,936,070	3·160	4·566 596 009	4,117,947
3·111	4·369 307 991	3,939,624	3·161	4·570 713 956	4,121,671
3·112	4·373 247 615	3,943,182	3·162	4·574 835 627	4,125,399
3·113	4·377 190 797	3,946,743	3·163	4·578 961 026	4,129,131
3·114	4·381 137 540	3,950,308	3·164	4·583 090 157	4,132,867
3·115	4·385 087 848	3,953,877	3·165	4·587 223 024	4,136,606
3·116	4·389 041 725	3,957,449	3·166	4·591 359 630	4,140,348
3·117	4·392 999 174	3,961,025	3·167	4·595 499 978	4,144,093
3·118	4·396 960 199	3,964,602	3·168	4·599 644 071	4,147,842
3·119	4·400 924 801	3,968,183	3·169	4·603 791 913	4,151,595
3·120	4·404 892 984	3,971,768	3·170	4·607 943 508	4,155,352
3·121	4·408 864 752	3,975,356	3·171	4·612 098 860	4,159,112
3·122	4·412 840 108	3,978,948	3·172	4·616 257 972	4,162,874
3·123	4·416 819 056	3,982,544	3·173	4·620 420 846	4,166,641
3·124	4·420 801 600	3,986,143	3·174	4·624 587 487	4,170,412
3·125	4·424 787 743	3,989,744	3·175	4·628 757 899	4,174,186
3·126	4·428 777 487	3,993,348	3·176	4·632 932 085	4,177,963
3·127	4·432 770 835	3,996,957	3·177	4·637 110 048	4,181,743
3·128	4·436 767 792	4,000,569	3·178	4·641 291 791	4,185,528
3·129	4·440 768 361	4,004,184	3·179	4·645 477 319	4,189,316
3·130	4·444 772 545	4,007,804	3·180	4·649 666 635	4,193,108
3·131	4·448 780 349	4,011,424	3·181	4·653 859 743	4,196,903
3·132	4·452 791 773	4,015,050	3·182	4·658 056 646	4,200,701
3·133	4·456 806 823	4,018,680	3·183	4·662 257 347	4,204,502
3·134	4·460 825 503	4,022,311	3·184	4·666 461 849	4,208,309
3·135	4·464 847 814	4,025,946	3·185	4·670 670 158	4,212,118
3·136	4·468 873 760	4,029,585	3·186	4·674 882 276	4,215,932
3·137	4·472 903 345	4,033,227	3·187	4·679 098 208	4,219,747
3·138	4·476 936 572	4,036,874	3·188	4·683 317 955	4,223,567
3·139	4·480 973 446	4,040,524	3·189	4·687 541 522	4,227,390
3·140	4·485 013 970	4,044,175	3·190	4·691 768 912	4,231,218
3·141	4·489 058 145	4,047,831	3·191	4·696 000 130	4,235,048
3·142	4·493 105 976	4,051,491	3·192	4·700 235 178	4,238,882
3·143	4·497 157 467	4,055,153	3·193	4·704 474 060	4,242,720
3·144	4·501 212 620	4,058,819	3·194	4·708 716 780	4,246,562
3·145	4·505 271 439	4,062,489	3·195	4·712 963 342	4,250,407
3·146	4·509 333 928	4,066,162	3·196	4·717 213 749	4,254,254
3·147	4·513 400 090	4,069,839	3·197	4·721 468 003	4,258,107
3·148	4·517 469 929	4,073,519	3·198	4·725 726 110	4,261,963
3·149	4·521 543 448	4,077,201	3·199	4·729 988 073	4,265,822
3·150	4·525 620 649	4,080,888	3·200	4·734 253 895	4,269,685

x	I_1x	Difference	x	I_1x	Difference
3·200	4·734 253 895	4,269,685	3·250	4·952 546 165	4,467,501
3·201	4·738 523 580	4,273,552	3·251	4·957 013 666	4,471,551
3·202	4·742 797 132	4,277,421	3·252	4·961 485 217	4,475,606
3·203	4·747 074 553	4,281,294	3·253	4·965 960 823	4,479,665
3·204	4·751 355 847	4,285,173	3·254	4·970 440 488	4,483,728
3·205	4·755 641 020	4,289,054	3·255	4·974 924 216	4,487,794
3·206	4·759 930 074	4,292,939	3·256	4·979 412 010	4,491,865
3·207	4·764 223 013	4,296,827	3·257	4·983 903 875	4,495,937
3·208	4·768 519 840	4,300,718	3·258	4·988 399 812	4,500,015
3·209	4·772 820 558	4,304,613	3·259	4·992 899 827	4,504,098
3·210	4·777 125 171	4,308,513	3·260	4·997 403 925	4,508,183
3·211	4·781 433 684	4,312,416	3·261	5·001 912 108	4,512,272
3·212	4·785 746 100	4,316,322	3·262	5·006 424 380	4,516,365
3·213	4·790 062 422	4,320,232	3·263	5·010 940 745	4,520,462
3·214	4·794 382 654	4,324,146	3·264	5·015 461 207	4,524,563
3·215	4·798 706 800	4,328,063	3·265	5·019 985 770	4,528,667
3·216	4·803 034 863	4,331,984	3·266	5·024 514 437	4,532,774
3·217	4·807 366 847	4,335,909	3·267	5·029 047 211	4,536,888
3·218	4·811 702 756	4,339,837	3·268	5·033 584 099	4,541,004
3·219	4 816 042 593	4,343,770	3·269	5·038 125 103	4,545,124
3·220	4·820 386 363	4,347,705	3·270	5·042 670 227	4,549,246
3·221	4·824 734 068	4,351,645	3·271	5·047 219 473	4,553,374
3·222	4·829 085 713	4,355,587	3·272	5·051 772 847	4,557,506
3·223	4·833 441 300	4,359,534	3·273	5 056 330 353	4,561,640
3·224	4·837 800 834	4,363,485	3·274	5·060 891 993	4,565,781
3·225	4·842 164 319	4,367,438	3·275	5·065 457 774	4,569,924
3·226	4·846 531 757	4,371,397	3·276	5·070 027 698	4,574,070
3·227	4·850 903 154	4,375,358	3·277	5·074 601 768	4,578,221
3·228	4·855 278 512	4,379,323	3·278	5·079 179 989	4,582,375
3·229	4·859 657 835	4,383,291	3·279	5·083 762 364	4,586,533
3·230	4·864 041 126	4,387,265	3·280	5·088 348 897	4,590,696
3·231	4·868 428 391	4,391,242	3·281	5·092 939 593	4,594,863
3·232	4·872 819 633	4,395,221	3·282	5·097 534 456	4,599,033
3·233	4·877 214 854	4,399,204	3·283	5·102 133 489	4,603,206
3·234	4·881 614 058	4,403,192	3·284	5·106 736 695	4,607,385
3·235	4·886 017 250	4,407,184	3·285	5·111 344 080	4,611,566
3·236	4·890 424 434	4,411,178	3·286	5·115 955 646	4,615,751
3·237	4·894 835 612	4,415,177	3·287	5·120 571 397	4,619,942
3·238	4·899 250 789	4,419,179	3·288	5·125 191 339	4,624,135
3·239	4·903 669 968	4,423,185	3·289	5·129 815 474	4,628,333
3·240	4·908 093 153	4,427,195	3·290	5·134 443 807	4,632,534
3·241	4·912 520 348	4,431,208	3·291	5·139 076 341	4,636,739
3·242	4·916 951 556	4,435,226	3·292	5·143 713 080	4,640,948
3·243	4·921 386 782	4,439,247	3·293	5·148 354 028	4,645,161
3·244	4·925 826 029	4,443,272	3·294	5·152 999 189	4,649,379
3·245	4·930 269 301	4,447,301	3·295	5·157 648 568	4,653,601
3·246	4·934 716 602	4,451,334	3·296	5·162 302 169	4,657,825
3·247	4·939 167 936	4,455,370	3·297	5·166 959 994	4,662,053
3·248	4·943 623 306	4,459,407	3·298	5·171 622 047	4.666,286
3·249	4·948 082 713	4,463,452	3·299	5·176 288 333	4,670,523
3·250	4·952 546 165	4,467,501	3·300	5·180 958 856	4,674,764

x	I_1x	Difference	x	I_1x	Difference
3·300	5·180 958 856	4,674,764	3·350	5·419 975 369	4,891,927
3·301	5·185 633 620	4,679,009	3·351	5·424 867 296	4,896,375
3·302	5·190 312 629	4,683,256	3·352	5·429 763 671	4,900,827
3·303	5·194 995 885	4,687,510	3·353	5·434 664 498	4,905,283
3·304	5·199 683 395	4,691,767	3·354	5·439 569 781	4,909,743
3·305	5·204 375 162	4,696,028	3·355	5·444 479 524	4,914,207
3·306	5·209 071 190	4,700,291	3·356	5·449 393 731	4,918,674
3·307	5·213 771 481	4,704,560	3·357	5·454 312 405	4,923,148
3·308	5·218 476 041	4,708,833	3·358	5·459 235 553	4,927,624
3·309	5·223 184 874	4,713,109	3·359	5·464 163 177	4,932,104
3·310	5·227 897 983	4,717,390	3·360	5·469 095 281	4,936,591
3·311	5·232 615 373	4,721,675	3·361	5·474 031 872	4,941,079
3·312	5·237 337 048	4,725,964	3·362	5·478 972 951	4,945,572
3·313	5·242 063 012	4,730,257	3·363	5·483 918 523	4,950,070
3·314	5·246 793 269	4,734,552	3·364	5·488 868 593	4,954,572
3·315	5·251 527 821	4,738,851	3·365	5·493 823 165	4,959,078
3·316	5·256 266 672	4,743,157	3·366	5·498 782 243	4,963,588
3·317	5·261 009 829	4,747,466	3·367	5·503 745 831	4,968,101
3·318	5·265 757 295	4,751,779	3·368	5·508 713 932	4,972,621
3·319	5·270 509 074	4,756,094	3·369	5·513 686 553	4,977,144
3·320	5·275 265 168	4,760,416	3·370	5·518 663 697	4,981,670
3·321	5·280 025 584	4,764,740	3·371	5·523 645 367	4,986,201
3·322	5·284 790 324	4,769,069	3·372	5·528 631 568	4,990,737
3·323	5·289 559 393	4,773,402	3·373	5·533 622 305	4,995,278
3·324	5·294 332 795	4,777,737	3·374	5·538 617 583	4,999,822
3·325	5·299 110 532	4,782,080	3·375	5·543 617 405	5,004,369
3·326	5·303 892 612	4,786,425	3·376	5·548 621 774	5,008,921
3·327	5·308 679 037	4,790,773	3·377	5·553 630 695	5,013,479
3·328	5·313 469 810	4,795,126	3·378	5·558 644 174	5,018,039
3·329	5·318 264 936	4,799,484	3·379	5·563 662 213	5,022,604
3·330	5·323 064 420	4,803,844	3·380	5·568 684 817	5,027,173
3·331	5·327 868 264	4,808,209	3·381	5·573 711 990	5,031,747
3·332	5·332 676 473	4,812,580	3·382	5·578 743 737	5,036,326
3·333	5·337 489 053	4,816,952	3·383	5·583 780 063	5,040,909
3·334	5·342 306 005	4,821,331	3·384	5·588 820 972	5,045,494
3·335	5·347 127 336	4,825,712	3·385	5·593 866 466	5,050,085
3·336	5·351 953 048	4,830,095	3·386	5·598 916 551	5,054,681
3·337	5·356 783 143	4,834,487	3·387	5·603 971 232	5,059,280
3·338	5·361 617 630	4,838,882	3·388	5·609 030 512	5,063,884
3·339	5·366 456 512	4,843,278	3·389	5·614 094 396	5,068,492
3·340	5·371 299 790	4,847,681	3·390	5·619 162 888	5,073,104
3·341	5·376 147 471	4,852,087	3·391	5·624 235 992	5,077,720
3·342	5·380 999 558	4,856,496	3·392	5·629 313 712	5,082,342
3·343	5·385 856 054	4,860,912	3·393	5·634 396 054	5,086,967
3·344	5·390 716 966	4,865,330	3·394	5·639 483 021	5,091,595
3·345	5·395 582 296	4,869,753	3·395	5·644 574 616	5,096,230
3·346	5·400 452 049	4,874,179	3·396	5·649 670 846	5,100,869
3·347	5·405 326 228	4,878,611	3·397	5·654 771 715	5,105,511
3·348	5·410 204 839	4,883,046	3·398	5·659 877 226	5,110,157
3·349	5·415 087 885	4,887,484	3·399	5·664 987 383	5,114,809
3·350	5·419 975 369	4,891,927	3·400	5·670 102 192	5,119,465

x	I_1x	Difference	x	I_1x	Difference
3·400	5·670 102 192	5,119,465	4·450	5·931 870 019	5,357,870
3·401	5·675 221 657	5,124,125	3·451	5·937 227 889	5,362,752
3·402	5·680 345 782	5,128,789	3·452	5·942 590 641	5,367,641
3·403	5·685 474 571	5,133,457	3·453	5·947 958 282	5,372,531
3·404	5·690 608 028	5,138,130	3·454	5·953 330 813	5,377,427
3·405	5·695 746 158	5,142,807	3·455	5·958 708 240	5,382.328
3·406	5·700 888 965	5,147,489	3·456	5·964 090 568	5,387,234
3·407	5·706 036 454	5,152,176	3·457	5·969 477 802	5,392,143
3·408	5·711 188 630	5,156,866	3·458	5·974 869 945	5,397,058
3·409	5·716 345 496	5,161,560	3·459	5·980 267 003	5,401,977
3·410	5·721 507 056	5,166,260	3·460	5·985 668 980	5,406,900
3·411	5·726 673 316	5,170,964	3·461	5·991 075 880	5,411,830
3·412	5·731 844 280	5,175,672	3·462	5·996 487 710	5,416,761
3·413	5·737 019 952	5,180,383	3·463	6·001 904 471	5,421,699
3·414	5·742 200 335	5,185,101	3·464	6·007 326 170	5,426,642
3·415	5·747 385 436	5,189,822	3·465	6·012 752 812	5,431,587
3·416	5·752 575 258	5,194,547	3·466	6·018 184 399	5,436,540
3·417	5·757 769 805	5,199,278	3·467	6·023 620 939	5,441,496
3·418	5·762 969 083	5,204,011	3·468	6·029 062 435	5,446,455
3·419	5·768 173 094	5,208,751	3·469	6·034 508 890	5,451,422
3·420	5·773 381 845	5,213,494	3·470	6·039 960 312	5,456,392
3·421	5·778 595 339	5,218,241	3·471	6·045 416 704	5,461,364
3·422	5·783 813 580	5,222,993	3·472	6·050 878 068	5,466,345
3·423	5·789 036 573	5,227,751	3·473	6·056 344 413	5,471,329
3·424	5·794 264 324	5,232,511	3·474	6·061 815 742	5,476,316
3·425	5·799 496 835	5,237,276	3·475	6·067 292 058	5,481,309
3·426	5·804 734 111	5,242,047	3·476	6·072 773 367	5,486,308
3·427	5·809 976 158	5,246,821	3·477	6·078 259 675	5,491,311
3·428	5·815 222 979	5,251,601	3·478	6·083 750 986	5,496,317
3·429	5·820 474 580	5,256,383	3·479	6·089 247 303	5,501,329
3·430	5·825 730 963	5,261,170	3·480	6·094 748 632	5,506,346
3·431	5·830 992 133	5,265,963	3·481	6·100 254 978	5,511,366
3·432	5·836 258 096	5,270,759	3·482	6·105 766 344	5,516,392
3·433	5·841 528 855	5,275,562	3·483	6·111 282 736	5,521,423
3·434	5·846 804 417	5,280,367	3·484	6·116 804 159	5,526,458
3·435	5·852 084 784	5,285,177	3·485	6·122 330 617	5,531,498
3·436	5·857 369 961	5,289,991	3·486	6·127 862 115	5,536,543
3·437	5·862 659 952	5,294,810	3·487	6·133 398 658	5,541,592
3·438	5·867 954 762	5,299,634	3·488	6·138 940 250	5,546,646
3·439	5·873 254 396	5,304,463	3·489	6·144 486 896	5,551,705
3·440	5·878 558 859	5,309,294	3·490	6·150 038 601	5,556,767
3·441	5·883 868 153	5,314,132	3·491	6·155 595 368	5,561,837
3·442	5·889 182 285	5,318,974	3·492	6·161 157 205	5,566,910
3·443	5·894 501 259	5,323,818	3·493	6·166 724 115	5,571,987
3·444	5·899 825 077	5,328,671	3·494	6·172 296 102	5,577,070
3·445	5·905 153 748	5,333,527	3·495	6·177 873 172	5,582,157
3·446	5·910 487 275	5,338,385	3·496	6·183 455 329	5,587,248
3·447	5·915 825 660	5,343,249	3·497	6·189 042 577	5,592,346
3·448	5·921 168 909	5,348,119	3·498	6·194 634 923	5,597,446
3·449	5·926 517 028	5,352,991	3·499	6·200 232 369	5,602,553
3·450	5·931 870 019	5,357,870	3·500	6·205 834 922	5,607,664

x	I_1x	Difference	x	I_1x	Difference
3·500	6·205 834 922	5,607,664	3·550	6·492 579 585	5,869,392
3·501	6·211 442 586	5,612,780	3·551	6·498 448 977	5,874,753
3·502	6·217 055 366	5,617,901	3·552	6·504 323 730	5,880,117
3·503	6·222 673 267	5,623,025	3·553	6·510 203 847	5,885,488
3·504	6·228 296 292	5,628,156	3·554	6·516 089 335	5,890,862
3·505	6·233 924 448	5,633,291	3·555	6·521 980 197	5,896,243
3·506	6·239 557 739	5,638,429	3·556	6·527 876 440	5,901,629
3·507	6·245 196 168	5,643,576	3·557	6·533 778 069	5,907,018
3·508	6·250 839 744	5,648,724	3·558	6·539 685 087	5,912,414
3·509	6·256 488 468	5,653,878	3·559	6·545 597 501	5,917,814
3·510	6·262 142 346	5,659,037	3·560	6·551 515 315	5,923,219
3·511	6·267 801 383	5,664,200	3·561	6·557 438 534	5,928,631
3·512	6·273 465 583	5,669,370	3·562	6·563 367 165	5,934,046
3·513	6·279 134 953	5,674,543	3·563	6·569 301 211	5,939,466
3·514	6·284 809 496	5,679,721	3·564	6·575 240 677	5,944,891
3·515	6·290 489 217	5,684,904	3·565	6·581 185 568	5,950,321
3·516	6·296 174 121	5,690,091	3·566	6·587 135 889	5,955,759
3·517	6·301 864 212	5,695,285	3·567	6·593 091 648	5,961,199
3·518	6·307 559 497	5,700,482	3·568	6·599 052 847	5,966,645
3·519	6·313 259 979	5,705,685	3·569	6·605 019 492	5,972,097
3·520	6·318 965 664	5,710,892	3·570	6·610 991 589	5,977,551
3·521	6·324 676 556	5,716,103	3·571	6·616 969 140	5,983,012
3·522	6·330 392 659	5,721,320	3·572	6·622 952 152	5,988,480
3·523	6·336 113 979	5,726,543	3·573	6·628 940 632	5,993,951
3·524	6·341 840 522	5,731,770	3·574	6·634 934 583	5,999,428
3·525	6·347 572 292	5,737,002	3·575	6·640 934 011	6,004,909
3·526	6·353 309 294	5,742,237	3·576	6·646 938 920	6,010,395
3·527	6·359 051 531	5,747,479	3·577	6·652 949 315	6,015,888
3·528	6·364 799 010	5,752,726	3·578	6·658 965 203	6,021,384
3·529	6·370 551 736	5,757,976	3·579	6·664 986 587	6,026,886
3·530	6·376 309 712	5,763,233	3·580	6·671 013 473	6,032,394
3·531	6·382 072 945	5,768,494	3·581	6·677 045 867	6,037,907
3·532	6·387 841 439	5,773,759	3·582	6·683 083 774	6,043,424
3·533	6·393 615 198	5,779,032	3·583	6·689 127 198	6,048,946
3·534	6·399 394 230	5,784,306	3·584	6·695 176 144	6,054,474
3·535	6·405 178 536	5,789,586	3·585	6·701 230 618	6,060,008
3·536	6·410 968 122	5,794,875	3·586	6·707 290 626	6,065,546
3·537	6·416 762 997	5,800,162	3·587	6·713 356 172	6,071,088
3·538	6·422 563 159	5,805,458	3·588	6·719 427 260	6,076,637
3·539	6·428 368 617	5,810,760	3·589	6·725 503 897	6,082,192
3·540	6·434 179 377	5,816,064	3·590	6·731 586 089	6,087,751
3·541	6·439 995 441	5,821,374	3·591	6·737 673 840	6,093,314
3·542	6·445 816 815	5,826,691	3·592	6·743 767 154	6,098.883
3·543	6·451 643 506	5,832,011	3·593	6·749 866 037	6,104,458
3·544	6 457 475 517	5,837,336	3·594	6·755 970 495	6,110,038
3·545	6·463 312 853	5,842,666	3·595	6·762 080 533	6,115,623
3·546	6·469 155 519	5,848,002	3·596	6·768 196 156	6,121,213
3·547	6·475 003 521	5,853,342	3·597	6·774 317 369	6,126,808
3·548	6·480 856 863	5,858,685	3·598	6·780 444 177	6,132,409
3·549	6·486 715 548	5,864,037	3·599	6·786 576 586	6,138,015
3·550	6·492 579 585	5,869,392	3·600	6·792 714 601	6,143,626

x	I_1x	Difference	x	I_1x	Difference
3·600	6·792 714 601	6,143,626	3·650	7·106 879 825	6,430,965
3·601	6·798 858 227	6,149,242	3·651	7·113 310 790	6,436,849
3·602	6·805 007 469	6,154,864	3·652	7·119 747 639	6,442,740
3·603	6·811 162 333	6,160,491	3·653	7·126 190 379	6,448,636
3·604	6·817 322 824	6,166,122	3·654	7·132 639 015	6,454,536
3·605	6·823 488 946	6,171,759	3·655	7·139 093 551	6,460,443
3·606	6·829 660 705	6,177,402	3·656	7·145 553 994	6,466,355
3·607	6·835 838 107	6,183,050	3·657	7·152 020 349	6,472,275
3·608	6·842 021 157	6,188,703	3·658	7·158 492 624	6,478,197
3·609	6·848 209 860	6,194,363	3 659	7·164 970 821	6,484,125
3·610	6·854 404 223	6,200,026	3·660	7·171 454 946	6,490,061
3·611	6·860 604 249	6,205,695	3·661	7·177 945 007	6,496,000
3·612	6·866 809 944	6,211,368	3·662	7·184 441 007	6,501,944
3·613	6·873 021 312	6,217,048	3·663	7·190 942 951	6,507,897
3·614	6·879 238 360	6,222,733	3·664	7·197 450 848	6,513,852
3·615	6·885 461 093	6,228,423	3·665	7·203 964 700	6,519,816
3·616	6·891 689 516	6,234,120	3·666	7·210 484 516	6,525,784
3·617	6·897 923 636	6,239,820	3·667	7·217 010 300	6,531,756
3·618	6·904 163 456	6,245,526	3·668	7·223 542 056	6,537,735
3·619	6·910 408 982	6,251,237	3·669	7·230 079 791	6,543,719
3·620	6·916 660 219	6,256,954	3·670	7·236 623 510	6,549,709
3·621	6·922 917 173	6,262,676	3·671	7·243 173 219	6,555,705
3·622	6·929 179 849	6,268,404	3·672	7·249 728 924	6,561,707
3·623	6·935 448 253	6,274,137	3·673	7·256 290 631	6,567,713
3·624	6·941 722 390	6,279,875	3·674	7·262 858 344	6,573,726
3·625	6·948 002 265	6,285,618	3 675	7·269 432 070	6,579,744
3·626	6·954 287 883	6,291,368	3·676	7·276 011 814	6,585,769
3·627	6·960 579 251	6,297,122	3·677	7·282 597 583	6,591,797
3·628	6·966 876 373	6,302,881	3·678	7·289 189 380	6,597,831
3·629	6·973 179 254	6,308,647	3·679	7·295 787 211	6,603,873
3·630	6·979 487 901	6,314,417	3·680	7·302 391 084	6,609,919
3·631	6·985 802 318	6,320,192	3·681	7·309 001 003	6,615,970
3·632	6·992 122 510	6,325,974	3·682	7·315 616 973	6,622,029
3·633	6·998 448 484	6,331,761	3·683	7·322 239 002	6,628,092
3·634	7·004 780 245	6,337,553	3·684	7·328 867 094	6,634,161
3·635	7·011 117 798	6,343,351	3·685	7·335 501 255	6,640,235
3·636	7·017 461 149	6,349,152	3·686	7·342 141 490	6,646,315
3·637	7·023 810 301	6,354,961	3·687	7·348 787 805	6,652,400
3·638	7·030 165 262	6,360,776	3·688	7·355 440 205	6,658,493
3·639	7·036 526 038	6,366,594	3·689	7·362 098 698	6,664,590
3·640	7·042 892 632	6,372,419	3·690	7·368 763 288	6,670,694
3·641	7·049 265 051	6,378,248	3·691	7·375 433 982	6,676,802
3·642	7·055 643 299	6,384,084	3·692	7·382 110 784	6,682,916
3·643	7·062 027 383	6,389,925	3·693	7·388 793 700	6,689,036
3·644	7·068 417 308	6,395,771	3·694	7·395 482 736	6,695,162
3·645	7·074 813 079	6,401,624	3·695	7·402 177 898	6,701,294
3·646	7·081 214 703	6,407,482	3·696	7·408 879 192	6,707,431
3·647	7·087 622 185	6,413,343	3·697	7·415 586 623	6,713,574
3·648	7·094 035 528	6,419,212	3·698	7·422 300 197	6,719,723
3·649	7·100 454 740	6,425,085	3·699	7·429 019 920	6,725,877
3·650	7·106 879 825	6,430,965	3·700	7·435 745 797	6,732,037

x	I_1x	Difference	x	I_1x	Difference
3·700	7·435 745 797	6,732,037	3·750	7·780 015 230	7,047,503
3·701	7·442 477 834	6,738,203	3·751	7·787 062 733	7,053,963
3·702	7·449 216 037	6,744,376	3·752	7·794 116 696	7,060,432
3·703	7·455 960 413	6,750,554	3·753	7·801 177 128	7,066,905
3·704	7·462 710 967	6,756,736	3·754	7·808 244 033	7,073,383
3·705	7·469 467 703	6,762,925	3·755	7·815 317 416	7,079,868
3·706	7·476 230 628	6,769,121	3·756	7·822 397 284	7,086,359
3·707	7·482 999 749	6,775,321	3·757	7·829 483 643	7,092,856
3·708	7·489 775 070	6,781,527	3·758	7·836 576 499	7,099,360
3·709	7·496 556 597	6,787,740	3·759	7·843 675 859	7,105,869
3·710	7·503 344 337	6,793,958	3·760	7·850 781 728	7,112,384
3·711	7·510 138 295	6,800,182	3·761	7·857 894 112	7,118,905
8·712	7·516 938 477	6,806,411	3·762	7·865 013 017	7,125,433
3·713	7·523 744 888	6,812,645	3·763	7·872 138 450	7,131,967
3·714	7·530 557 533	6,818,889	3·764	7·879 270 417	7,138,507
3·715	7·537 376 422	6,825,136	3·765	7·886 408 924	7,145,053
3·716	7·544 201 558	6,831,389	3·766	7·893 553 977	7,151,604
3·717	7·551 032 947	6,837,647	3·767	7·900 705 581	7,158,162
3·718	7·557 870 594	6,843,911	3·768	7·907 863 743	7,164,727
3·719	7·564 714 505	6,850,182	3·769	7·915 028 470	7,171,297
3·720	7·571 564 687	6,856,458	3·770	7·922 199 767	7,177,874
3·721	7·578 421 145	6,862,742	3·771	7·929 377 641	7,184,456
3·722	7·585 283 887	6,869,029	3·772	7·936 562 097	7,191,045
3·723	7·592 152 916	6,875,323	3·773	7·943 753 142	7,197,640
3·724	7·599 028 239	6,881,623	3·774	7·950 950 782	7,204,242
3·725	7·605 909 862	6,887,930	3·775	7·958 155 024	7,210,849
3·726	7·612 797 792	6,894,240	3·776	7·965 365 873	7,217,462
3·727	7·619 692 032	6,900,558	3·777	7·972 583 335	7,224,082
3·728	7·626 592 590	6,906,882	3·778	7·979 807 417	7,230,708
3·729	7·633 499 472	6,913,212	3·779	7·987 038 125	7,237,340
3·730	7·640 412 684	6,919,547	3·780	7·994 275 465	7,243,977
3·731	7·647 332 231	6,925,887	3·781	8·001 519 442	7,250,622
3·732	7·654 258 118	6,932,235	3·782	8·008 770 064	7,257,273
3·733	7·661 190 353	6,938,588	3·783	8·016 027 337	7,263,930
3·734	7·668 128 941	6,944,947	3·784	8·023 291 267	7,270,594
3·735	7·675 073 888	6,951,312	3·785	8·030 561 861	7,277,262
3·736	7·682 025 200	6,957,683	3·786	8·037 839 123	7,283,938
3·737	7·688 982 883	6,964,059	3·787	8·045 123 061	7,290,620
3·738	7·695 946 942	6,970,442	3·788	8·052 413 681	7,297,308
3·739	7·702 917 384	6,976,832	3·789	8·059 710 989	7,304,002
3·740	7·709 894 216	6,983,227	3·790	8·067 014 991	7,310,703
3·741	7·716 877 443	6,989,626	3·791	8·074 325 694	7,317,410
3·742	7·723 867 069	6,996,034	3·792	8·081 643 104	7,324,122
3·743	7·730 863 103	7,002,447	3·793	8·088 967 226	7,330,841
3·744	7·737 865 550	7,008,864	3·794	8·096 298 067	7,337,568
3·745	7·744 874 414	7,015,289	3·795	8·103 635 635	7,344,301
3·746	7·751 889 703	7,021,721	3·796	8·110 979 936	7,351,038
3·747	7·758 911 424	7,028,158	3·797	8·118 330 974	7,357,782
3·748	7·765 939 582	7,034,600	3·798	8·125 688 756	7,364,533
3·749	7·772 974 182	7,041,048	3·799	8·133 053 289	7,371,290
3·750	7·780 015 230	7,047,503	3·800	8·140 424 579	7,378,054

x	I_1x	Difference	x	I_1x	Difference
3·800	8·140 424 579	7,378,054	3·850	8 517 745 677	7,724,413
3·801	8·147 802 633	7,384,823	3·851	8·525 470 090	7,731,506
3·802	8·155 187 456	7,391,600	3·852	8·533 201 596	7,738,608
3·803	8·162 579 056	7,398,382	3·853	8·540 940 204	7,745,715
3·804	8·169 977 438	7,405,171	3·854	8·548 685 919	7,752,827
3·805	8·177 382 609	7,411,966	3·855	8·556 438 746	7,759,947
3·806	8·184 794 575	7,418,767	3·856	8·564 198 693	7,767,074
3·807	8·192 213 342	7,425,576	3·857	8·571 965 767	7,774,208
3·808	8·199 638 918	7,432,390	3·858	8·579 739 975	7,781,348
3·809	8·207 071 308	7,439,210	3·859	8·587 521 323	7,788,495
3·810	8·214 510 518	7,446,037	3·860	8·595 309 818	7,795,649
3·811	8·221 956 555	7,452,870	3·861	8·603 105 467	7,802,809
3·812	8·229 409 425	7,459,710	3·862	8·610 908 276	7,809,975
3·813	8·236 869 135	7,466,556	3·863	8·618 718 251	7,817,150
3·814	8·244 335 691	7,473,410	3·864	8·626 535 401	7,824,330
3·815	8·251 809 101	7,480,268	3·865	8·634 359 731	7,831,516
3·816	8·259 289 369	7,487,134	3·866	8·642 191 247	7,838,711
3·817	8·266 776 503	7,494,005	3·867	8·650 029 958	7,845,911
3·818	8·274 270 508	7,500,883	3·868	8·657 875 869	7,853,118
3·819	8·281 771 391	7,507,768	3·869	8·665 728 987	7,860,331
3·820	8·289 279 159	7,514,658	3·870	8·673 589 318	7,867,553
3·821	8·296 793 817	7,521,556	3·871	8·681 456 871	7,874,781
3·822	8·304 315 373	7,528,460	3·872	8·689 331 652	7,882,014
3·823	8·311 843 833	7,535,370	3·873	8·697 213 666	7,889,255
3·824	8·319 379 203	7,542,288	3·874	8·705 102 921	7,896,503
3·825	8·326 921 491	7,549,211	3·875	8·712 999 424	7,903,757
3·826	8·334 470 702	7,556,140	3·876	8·720 903 181	7,911,019
3·827	8·342 026 842	7,563,077	3·877	8·728 814 200	7,918,287
3·828	8·349 589 919	7,570,020	3·878	8·736 732 487	7,925,562
3·829	8·357 159 939	7,576,968	3·879	8·744 658 049	7,932,844
3·830	8·364 736 907	7,583,925	3·880	8·752 590 893	7,940,132
3·831	8·372 320 832	7,590,887	3·881	8·760 531 025	7,947,427
3·832	8·379 911 719	7,597,856	3·882	8·768 478 452	7,954,730
3·833	8·387 509 575	7,604,830	3·883	8·776 433 182	7,962,038
3·834	8·395 114 405	7,611,813	3·884	8·784 395 220	7,969,354
3·835	8·402 726 218	7,618,801	3·885	8·792 364 574	7,976,677
3·836	8·410 345 019	7,625,795	3·886	8·800 341 251	7,984,007
3·837	8·417 970 814	7,632,797	3·887	8·808 325 258	7,991,343
3·838	8·425 603 611	7,639,806	3·888	8·816 316 601	7,998,685
3·839	8·433 243 417	7,646,819	3·889	8·824 315 286	8,006,036
3·840	8.440 890 236	7,653,840	3·890	8·832 321 322	8,013,393
3·841	8·448 544 076	7,660,869	3·891	8·840 334 715	8,020,757
3·842	8·456 204 945	7,667,902	3·892	8·848 355 472	8,028,127
3·843	8·463 872 847	7,674,944	3·893	8·856 383 599	8,035,506
3·844	8·471 547 791	7,681,991	3·894	8·864 419 105	8,042,890
3·845	8·479 229 782	7,689,045	3·895	8·872 461 995	8,050,280
3·846	8·486 918 827	7,696,105	3·896	8·880 512 275	8,057,680
3·847	8·494 614 932	7,703,172	3·897	8·888 569 955	8,065,085
3·848	8·502 318 104	7,710,246	3·898	8·896 635 040	8,072,496
3·849	8·510 028 350	7,717,327	3·899	8·904 707 536	8,079,915
3·850	8·517 745 677	7,724,413	3·900	8·912 787 451	8,087,342

x	I_1x	Difference	x	I_1x	Difference
3·900	8·912 787 451	8,087,342	3·950	9·326 397 737	8,467,636
3·901	8·920 874 793	8,094,775	3·951	9·334 865 373	8,475,426
3·902	8·928 969 568	8,102,216	3·952	9·343 340 799	8,483,222
3·903	8·937 071 784	8,109,662	3·953	9·351 824 021	8,491,024
3·904	8·945 181 446	8,117,115	3·954	9·360 315 045	8,498,836
3·905	8·953 298 561	8,124,577	3·955	9·368 813 881	8,506,654
3·906	8·961 423 138	8,132,045	3·956	9·377 320 535	8,514,478
3·907	8·969 555 183	8,139,519	3·957	9·385 835 013	8,522,311
3·908	8·977 694 702	8,147,001	3·958	9·394 357 324	8,530,151
3·909	8·985 841 703	8,154,490	3·959	9·402 887 475	8,537,998
3·910	8·993 996 193	8,161,985	3·960	9·411 425 473	8,545,853
3·911	9·002 158 178	8,169,488	3·961	9·419 971 326	8,553,715
3·912	9·010 327 666	8,176,998	3·962	9·428 525 041	8,561,583
3·913	9·018 504 664	8,184,515	3·963	9·437 086 624	8,569,461
3·914	9·026 689 179	8,192,039	3·964	9·445 656 085	8,577,344
3·915	9·034 881 218	8,199,570	3·965	9·454 233 429	8,585,235
3·916	9·043 080 788	8,207,107	3·966	9·462 818 664	8,593,136
3·917	9·051 287 895	8,214,653	3·967	9·471 411 800	8,601,040
3·918	9·059 502 548	8,222,205	3·968	9·480 012 840	8,608,953
3·919	9·067 724 753	8,229,764	3·969	9·488 621 793	8,616,875
3·920	9·075 954 517	8,237,330	3·970	9·497 238 668	8,624,804
3·921	9·084 191 847	8,244,904	3·971	9·505 863 472	8,632,739
3·922	9·092 436 751	8,252,484	3·972	9·514 496 211	8,640,683
3·923	9·100 689 235	8,260,070	3·973	9·523 136 894	8,648,633
3·924	9·108 949 305	8,267,667	3·974	9·531 785 527	8,656,590
3·925	9·117 216 972	8,275,266	3·975	9·540 442 117	8,664,557
3·926	9·125 492 238	8,282,876	3·976	9·549 106 674	8,672,530
3·927	9·133 775 114	8,290,492	3·977	9·557 779 204	8,680,509
3·928	9·142 065 606	8,298,116	3·978	9·566 459 713	8,688,498
3·929	9·150 363 722	8,305,745	3·979	9·575 148 211	8,696,493
3·930	9·158 669 467	8,313,382	3·980	9·583 844 704	8,704,495
3·931	9·166 982 849	8,321,027	3·981	9·592 549 199	8,712,505
3·932	9·175 303 876	8,328,678	3·982	9·601 261 704	8,720,525
3·933	9·183 632 554	8,336,337	3·983	9·609 982 229	8,728,549
3·934	9·191 968 891	8,344,003	3·984	9·618 710 778	8,736,581
3·935	9·200 312 894	8,351,677	3·985	9·627 447 359	8,744,623
3·936	9·208 664 571	8,359,356	3·986	9·636 191 982	8,752,670
3·937	9·217 023 927	8,367,043	3·987	9·644 944 652	8,760,726
3·938	9·225 390 970	8,374,737	3·988	9·653 705 378	8,768,788
3·939	9·233 765 707	8,382,440	3·989	9·662 474 166	8,776,859
3·940	9·242 148 147	8,390,150	3·990	9·671 251 025	8,784,936
3·941	9·250 538 297	8,397,866	3·991	9·680 035 961	8,793,023
3·942	9·258 936 163	8,405,589	3·992	9·688 828 984	8,801,116
3·943	9·267 341 752	8,413,319	3·993	9·697 630 100	8,809,216
3·944	9·275 755 071	8,421,057	3·994	9·706 439 316	8,817,325
3·945	9·284 176 128	8,428,802	3·995	9·715 256 641	8,825,440
3·946	9·292 604 930	8,436,555	3·996	9·724 082 081	8,833,564
3·947	9·301 041 485	8,444,315	3·997	9·732 915 645	8,841,696
3·948	9·309 485 800	8,452,082	3·998	9·741 757 341	8,849,833
3·949	9·317 937 882	8,459,855	3·999	9·750 607 174	8,857,980
3·950	9·326 397 737	8,467,636	4·000	9·759 465 154	8,866,134

x	I_1x	Difference	x	I_1x	Difference
4·000	9·759 465 154	8,866,134	4·050	10·212 921 103	9,283,709
4·001	9·768 331 288	8,874,295	4·051	10·222 204 812	9,292,262
4·002	9·777 205 583	8,882,464	4·052	10·231 497 074	9,300,821
4·003	9·786 088 047	8,890,642	4·053	10·240 797 895	9,309,391
4·004	9·794 978 689	8,898,826	4·054	10·250 107 286	9,317,967
4·005	9·803 877 515	8,907,018	4·055	10·259 425 253	9,326,552
4·006	9·812 784 533	8,915,218	4·056	10·268 751 805	9,335,143
4·007	9·821 699 751	8,923,425	4·057	10·278 086 948	9,343,743
4·008	9·830 623 176	8,931,641	4·058	10·287 430 691	9,352,354
4·009	9·839 554 817	8,939,864	4·059	10·296 783 045	9,360,971
4·010	9·848 494 681	8,948,093	4·060	10·306 144 016	9,369,592
4·011	9·857 442 774	8,956,332	4·061	10·315 513 608	9,378,226
4·012	9·866 399 106	8,964,579	4·062	10·324 891 834	9,386,867
4·013	9·875 363 685	8,972,831	4·063	10·334 278 701	9,395,516
4·014	9·884 336 516	8,981,093	4·064	10·343 674 217	9,404,174
4·015	9·893 317 609	8,989,363	4·065	10·353 078 391	9,412,839
4·016	9·902 306 972	8,997,639	4·066	10·362 491 230	9,421,512
4·017	9·911 304 611	9,005,923	4·067	10·371 912 742	9,430,192
4·018	9·920 310 534	9,014,217	4·068	10·381 342 934	9,438,883
4·019	9·929 324 751	9,022,516	4·069	10·390 781 817	9,447,580
4·020	9·938 347 267	9,030,824	4·070	10·400 229 397	9,456,285
4·021	9·947 378 091	9,039,140	4·071	10·409 685 682	9,465,000
4·022	9·956 417 231	9,047,463	4·072	10·419 150 682	9,473,722
4·023	9·965 464 694	9,055,794	4·073	10·428 624 404	9,482,450
4·024	9·974 520 488	9,064,135	4·074	10·438 106 854	9,491,192
4·025	9·983 584 623	9,072,480	4·075	10·447 598 046	9,499,937
4·026	9·992 657 103	9,080,835	4·076	10·457 097 983	9,508,690
4·027	10·001 737 938	9,089,197	4·077	10·466 606 673	9,517,454
4·028	10·010 827 135	9,097,567	4·078	10·476 124 127	9,526,227
4·029	10·019 924 702	9,105,948	4·079	10·485 650 354	9,535,005
4·030	10·029 030 650	9,114,331	4·080	10·495 185 359	9,543,792
4·031	10·038 144 981	9,122,725	4·081	10·504 729 151	9,552,589
4·032	10·047 267 706	9,131,128	4·082	10·514 281 740	9,561,393
4·033	10·056 398 834	9,139,538	4·083	10·523 843 133	9,570,205
4·034	10·065 538 372	9,147,953	4·084	10·533 413 338	9,579,025
4·035	10·074 686 325	9,156,378	4·085	10·542 992 363	9,587,854
4·036	10·083 842 703	9,164,814	4·086	10·552 580 217	9,596,690
4·037	10·093 007 517	9,173,252	4·087	10·562 176 907	9,605,537
4·038	10·102 180 769	9,181,705	4·088	10·571 782 444	9,614,390
4·039	10·111 362 474	9,190,160	4·089	10·581 396 834	9,623,251
4·040	10·120 552 634	9,198,625	4·090	10·591 020 085	9,632,122
4·041	10·129 751 259	9,207,096	4·091	10·600 652 207	9,641,001
4·042	10·138 958 355	9,215,578	4·092	10·610 293 208	9,649,887
4·043	10·148 173 933	9,224,066	4·093	10·619 943 095	9,658,783
4·044	10·157 397 999	9,232,563	4·094	10·629 601 878	9,667,686
4·045	10·166 630 562	9,241,068	4·095	10·639 269 564	9,676,598
4·046	10·175 871 630	9,249,579	4·096	10·648 946 162	9,685,518
4·047	10·185 121 209	9,258,100	4·097	10·658 631 680	9,694,446
4·048	10·194 379 309	9,266,629	4·098	10·668 326 126	9,703,383
4·049	10·203 645 938	9,275,165	4·099	10·678 029 509	9,712,328
4·050	10·212 921 103	9,283,709	4·100	10·687 741 837	9,721,281

x	I_1x	Difference	x	I_1x	Difference
4·100	10·687 741 837	9,721,281	4·150	11·184 950 646	10,179,815
4·101	10·697 463 118	9,730,245	4·151	11·195 130 461	10,189,207
4·102	10·707 193 363	9,739,215	4·152	11·205 319 668	10,198,607
4·103	10·716 932 578	9,748,193	4·153	11·215 518 275	10,208,017
4·104	10·726 680 771	9,757,179	4·154	11·225 726 292	10,217,434
4·105	10·736 437 950	9,766,176	4·155	11·235 943 726	10,226,861
4·106	10·746 204 126	9,775,181	4·156	11·246 170 587	10,236,296
4·107	10·755 979 307	9,784,192	4·157	11·256 406 883	10,245,740
4·108	10·765 763 499	9,793,214	4·158	11·266 652 623	10,255,192
4·109	10·775 556 713	9,802,243	4·159	11·276 907 815	10,264,656
4·110	10·785 358 956	9,811,280	4·160	11·287 172 471	10,274,127
4·111	10·795 170 236	9,820,326	4·161	11·297 446 598	10,283,606
4·112	10·804 990 562	9,829,381	4·162	11·307 730 204	10,293,094
4·113	10·814 819 943	9,838,444	4·163	11·318 023 298	10,302,591
4·114	10·824 658 387	9,847,516	4·164	11·328 325 889	10,312,098
4·115	10·834 505 903	9,856,596	4·165	11·338 637 987	10,321,613
4·116	10·844 362 499	9,865,685	4·166	11·348 959 600	10,331,138
4·117	10·854 228 184	9,874,782	4·167	11·359 290 738	10,340,670
4·118	10·864 102 966	9,883,889	4·168	11·369 631 408	10,350,213
4·119	10·873 986 855	9,893,001	4·169	11·379 981 621	10,359,763
4·120	10·883 879 856	9,902,124	4·170	11·390 341 384	10,369,323
4·121	10·893 781 980	9,911,258	4·171	11·400 710 707	10,378,892
4·122	10·903 693 238	9,920,396	4·172	11·411 089 599	10,388,470
4·123	10·913 613 634	9,929,543	4·173	11·421 478 069	10,398,057
4·124	10·923 543 177	9,938,701	4·174	11·431 876 126	10,407,652
4·125	10·933 481 878	9,947,867	4·175	11·442 283 778	10,417,258
4·126	10·943 429 745	9,957,041	4·176	11·452 701 036	10,426,871
4·127	10·953 386 786	9,966,223	4·177	11·463 127 907	10,436,494
4·128	10·963 353 009	9,975,414	4·178	11·473 564 401	10,446,124
4·129	10·973 328 423	9,984,615	4·179	11·484 010 525	10,455,767
4·130	10·983 313 038	9,993,824	4·180	11·494 466 292	10,465,416
4·131	10·993 306 862	10,003,041	4·181	11·504 931 708	10,475,074
4·132	11·003 309 903	10,012,266	4·182	11·515 406 782	10,484,742
4·133	11·013 322 169	10,021,501	4·183	11·525 891 524	10,494,419
4·134	11·023 343 670	10,030,744	4·184	11·536 385 943	10,504,106
4·135	11·033 374 414	10,039,995	4·185	11·546 890 049	10,513,802
4·136	11·043 414 409	10,049,256	4·186	11·557 403 851	10,523,503
4·137	11·053 463 665	10,058,525	4·187	11·567 927 354	10,533,219
4·138	11·063 522 190	10,067,802	4·188	11·578 460 573	10,542,940
4·139	11·073 589 992	10,077,089	4·189	11·589 003 513	10,552,671
4·140	11·083 667 081	10,086,385	4·190	11·599 556 184	10,562,412
4·141	11·093 753 466	10,095,688	4·191	11·610 118 596	10,572,163
4·142	11·103 849 154	10,105,002	4·192	11·620 690 759	10,581,922
4·143	11·113 954 156	10,114,322	4·193	11·631 272 681	10,591,689
4·144	11·124 068 478	10,123,652	4·194	11·641 864 370	10,601,466
4·145	11·134 192 130	10,132,991	4·195	11·652 465 836	10,611,252
4·146	11·144 325 121	10,142,338	4·196	11·663 077 088	10,621,048
4·147	11·154 467 459	10,151,694	4·197	11·673 698 136	10,630,852
4·148	11·164 619 153	10,161,059	4·198	11·684 328 988	10,640,666
4·149	11·174 780 212	10,170,434	4·199	11·694 969 654	10,650,489
4·150	11·184 950 646	10,179,815	4·200	11·705 620 143	10,660,322

x	I_1x	Difference	x	I_1x	Difference
4·200	11·705 620 143	10,660,322	4·250	12·250 874 666	11,163,862
4·201	11·716 280 465	10,670,162	4·251	12·262 038 528	11,174,170
4·202	11·726 950 627	10,680,013	4·252	12·273 212 698	11,184,494
4·203	11·737 630 640	10,689,874	4·253	12·284 397 192	11,194,827
4·204	11·748 320 514	10,699,743	4·254	12·295 592 019	11,205,169
4·205	11·759 020 257	10,709,620	4·255	12·306 797 188	11,215,521
4·206	11·769 729 877	10,719,508	4·256	12·318 012 709	11,225,883
4·207	11·780 449 385	10,729,406	4·257	12·329 238 592	11,236,254
4·208	11·791 178 791	10,739,311	4·258	12·340 474 846	11,246,635
4·209	11·801 918 102	10,749,226	4·259	12·351 721 481	11,257,026
4·210	11·812 667 328	10,759,151	4·260	12·362 978 507	11,267,427
4·211	11·823 426 479	10,769,086	4·261	12·374 245 934	11,277,836
4·212	11·834 195 565	10,779,029	4·262	12·385 523 770	11,288,256
4·213	11·844 974 594	10,788,981	4·263	12·396 812 026	11,298,687
4·214	11·855 763 575	10,798,944	4·264	12·408 110 713	11,309,127
4·215	11·866 562 519	10,808,915	4·265	12·419 419 840	11,319,576
4·216	11·877 371 434	10,818,895	4·266	12·430 739 416	11,330,034
4·217	11·888 190 329	10,828,885	4·267	12·442 069 450	11,340,503
4·218	11·899 019 214	10,838,885	4·268	12·453 409 953	11,350,982
4·219	11·909 858 099	10,848,893	4·269	12·464 760 935	11,361,471
4·220	11·920 706 992	10,858,911	4·270	12·476 122 406	11,371,969
4·221	11·931 565 903	10,868,938	4·271	12·487 494 375	11,382,475
4·222	11·942 434 841	10,878,976	4·272	12·498 876 850	11,392,996
4·223	11·953 313 817	10,889,023	4·273	12·510 269 846	11,403,525
4·224	11·964 202 840	10,899,078	4·274	12·521 673 371	11,414,061
4·225	11·975 101 918	10,909,142	4·275	12·533 087 432	11,424,608
4·226	11·986 011 060	10,919,217	4·276	12·544 512 040	11,435,166
4·227	11·996 930 277	10,929,302	4·277	12·555 947 206	11,445,734
4·228	12·007 859 579	10,939,394	4·278	12·567 392 940	11,456,312
4·229	12·018 798 973	10,949,497	4·279	12·578 849 252	11,466,898
4·230	12·029 748 470	10,959,610	4·280	12·590 316 150	11,477,495
4·231	12·040 708 080	10,969,732	4·281	12·601 793 645	11,488,103
4·232	12·051 677 812	10,979,863	4·282	12·613 281 748	11,498,720
4·233	12·062 657 675	10,990,004	4·283	12·624 780 468	11,509,347
4·234	12·073 647 679	11,000,154	4·284	12·636 289 815	11,519,984
4·235	12·084 647 833	11,010,314	4·285	12·647 809 799	11,530,630
4·236	12·095 658 147	11,020,483	4·286	12·659 340 429	11,541,288
4·237	12·106 678 630	11,030,662	4·287	12·670 881 717	11,551,955
4·238	12·117 709 292	11,040,850	4·288	12·682 433 672	11,562,632
4·239	12·128 750 142	11,051,049	4·289	12·693 996 304	11,573,318
4·240	12·139 801 191	11,061,256	4·290	12·705 569 622	11,584,015
4·241	12·150 862 447	11,071,472	4·291	12·717 153 637	11,594,722
4·242	12·161 933 919	11,081,700	4·292	12·728 748 359	11,605,440
4·243	12·173 015 619	11,091,936	4·293	12·740 353 799	11,616,167
4·244	12·184 107 555	11,102,182	4·294	12·751 969 966	11,626,904
4·245	12·195 209 737	11,112,435	4·295	12·763 596 870	11,637,650
4·246	12·206 322 172	11,122,703	4·296	12·775 234 520	11,648,407
4·247	12·217 444 875	11,132,977	4·297	12·786 882 927	11,659,176
4·248	12·228 577 852	11,143,260	4·298	12·798 542 103	11,669,953
4·249	12·239 721 112	11,153,554	4·299	12·810 212 056	11,680,740
4·250	12·250 874 666	11,163,862	4·300	12·821 892 796	11,691,537

x	I_1x	Difference	x	I_1x	Difference
4·300	12·821 892 796	11,691,537	4·350	13·419 909 985	12,244,526
4·301	12·833 584 333	11,702,346	4·351	13·432 154 511	12,255,850
4·302	12·845 286 679	11,713,164	4·352	13·444 410 361	12,267,189
4·303	12·856 999 843	11,723,993	4·353	13·456 677 550	12,278,536
4·304	12·868 723 836	11,734,830	4·354	13·468 956 086	12,289,895
4·305	12·880 458 666	11,745,678	4·355	13·481 245 981	12,301,263
4·306	12·892 204 344	11,756,537	4·356	13·493 547 244	12,312,642
4·307	12·903 960 881	11,767,405	4·357	13·505 859 886	12,324,032
4·308	12·915 728 286	11,778,284	4·358	13·518 183 918	12,335,433
4·309	12·927 506 570	11,789,173	4·359	13·530 519 351	12,346,845
4·310	12·939 295 743	11,800,073	4·360	13·542 866 196	12,358,267
4·311	12·951 095 816	11,810,982	4·361	13·555 224 463	12,369,700
4·312	12·962 906 798	11,821,902	4·362	13·567 594 163	12,381,143
4·313	12·974 728 700	11,832,832	4·363	13·579 975 306	12,392,598
4·314	12·986 561 532	11,843,772	4·364	13·592 367 904	12,404,062
4·315	12·998 405 304	11,854,722	4·365	13·604 771 966	12,415,538
4·316	13·010 260 026	11,865,683	4·366	13·617 187 504	12,427,025
4·317	13·022 125 709	11,876,655	4·367	13·629 614 529	12,438,522
4·318	13·034 002 364	11,887,635	4·368	13·642 053 051	12,450,030
4·319	12·045 889 999	11,898,627	4·369	13·654 503 081	12,461,549
4·320	13·057 788 626	11,909,629	4·370	13·666 964 630	12,473,079
4·321	13·069 698 255	11,920,642	4·371	13·679 437 709	12,484,620
4·322	13·081 618 897	11,931,663	4·372	13·691 922 329	12,496,170
4·323	13·093 550 560	11,942,697	4·373	13·704 418 499	12,507,733
4·324	13·105 493 257	11,953,739	4·374	13·716 926 232	12,519,306
4·325	13·117 446 996	11,964,793	4·375	13·729 445 538	12,530,890
4·326	13·129 411 789	11,975,857	4·376	13·741 976 428	12,542,484
4·327	13·141 387 646	11,986,931	4·377	13·754 518 912	12,554,090
4·328	13·153 374 577	11,998,017	4·378	13·767 073 002	12,565,707
4·329	13·165 372 594	12,009,111	4·379	13·779 638 709	12,577,334
4·330	13·177 381 705	12,020,217	4·380	13·792 216 043	12,588,972
4·331	13·189 401 922	12,031,333	4·381	13·804 805 015	12,600,621
4·332	13·201 433 255	12,042,459	4·382	13·817 405 636	12,612,282
4·333	13·213 475 714	12,053,595	4·383	13·830 017 918	12,623,953
4·334	13·225 529 309	12,064,743	4·384	13·842 641 871	12,635,634
4·335	13·237 594 052	12,075,900	4·385	13·855 277 505	12,647,327
4·336	13·249 669 952	12,087,068	4·386	13·867 924 832	12,659,031
4·337	13·261 757 020	12,098,248	4·387	13·880 583 863	12,670,747
4·338	13·273 855 268	12,109,437	4·388	13·893 254 610	12,682,472
4·339	13·285 964 705	12,120,635	4·389	13·905 937 082	12,694,209
4·340	13·298 085 340	12,131,845	4·390	13·918 631 291	12,705,957
4·341	13·310 217 185	12,143,067	4·391	13·931 337 248	12,717,716
4·342	13·322 360 252	12,154,297	4·392	13·944 054 964	12,729,486
4·343	13·334 514 549	12,165,538	4·393	13·956 784 450	12,741,267
4·344	13·346 680 087	12,176,791	4·394	13·969 525 717	12,753,058
4·345	13·358 856 878	12,188,054	4·395	13·982 278 775	12,764,862
4·346	13·371 044 932	12,199,327	4·396	13·995 043 637	12,776,677
4·347	13·383 244 259	12,210,610	4·397	14·007 820 314	12,788,501
4·348	13·395 454 869	12,221,907	4·398	14·020 608 815	12,800,338
4·349	13·407 676 776	12,233,209	4·399	14·033 409 153	12,812,185
4·350	13·419 909 985	12,244,526	4·400	14·046 221 338	12,824,043

x	I_1x	Difference	x	I_1x	Difference
4·400	14·046 221 338	12,824,043	4·450	14·702 184 510	13,431,374
4·401	14·059 045 381	12,835,913	4·451	14·715 615 884	13,443,813
4·402	14·071 881 294	12,847,794	4·452	14·729 059 697	13,456,264
4·403	14·084 729 088	12,859,686	4·453	14·742 515 961	13,468,727
4·404	14·097 588 774	12,871,589	4·454	14·755 984 688	13,481,201
4·405	14·110 460 363	12,883,504	4·455	14·769 465 889	13,493,686
4·406	14·123 343 867	12,895,429	4·456	14·782 959 575	13,506,186
4·407	14·136 239 296	12,907,366	4·457	14·796 465 761	13,518,696
4·408	14·149 146 662	12,919,313	4·458	14·809 984 457	13,531,215
4·409	14·162 065 975	12,931,272	4·459	14·823 515 672	13,543,748
4·410	14·174 997 247	12,943,242	4·460	14·837 059 420	13,556,293
4·411	14·187 940 489	12,955,225	4·461	14·850 615 713	13,568,851
4·412	14·200 895 714	12,967,217	4·462	14·864 184 564	13,581,420
4·413	14·213 862 931	12,979,220	4·463	14·877 765 984	13,593,998
4·414	14·226 842 151	12,991,235	4·464	14·891 359 982	13,606,591
4·415	14·239 833 386	13,003,262	4·465	14·904 966 573	13,619,194
4·416	14·252 836 648	13,015,300	4·466	14·918 585 767	13,631,811
4·417	14·265 851 948	13,027,350	4·467	14·932 217 578	13,644,439
4·418	14·278 879 298	13,039,410	4·468	14·945 862 017	13,657,077
4·419	14·291 918 708	13,051,481	4·469	14·959 519 094	13,669,728
4·420	13·304 970 189	13,063,564	4·470	14·973 188 822	13,682,391
4·421	14·318 033 753	13,075,659	4·471	14·986 871 213	13,695,068
4·422	14·331 109 412	13,087,765	4·472	15·000 566 281	13,707,753
4·423	14·344 197 177	13,099,881	4·473	15·014 274 034	13,720,451
4·424	14·357 297 058	13,112,010	4·474	15·027 994 485	13,733,163
4·425	14·370 409 068	13,124,150	4·475	15·041 727 648	13,745,885
4·426	14·383 533 218	13,136,300	4·476	15·055 473 533	13,758,620
4·427	14·396 669 518	13,148,463	4·477	15·069 232 153	13,771,366
4·428	14·409 817 981	13,160,636	4·478	15·083 003 519	13,784,124
4·429	14·422 978 617	13,172,823	4·479	15·096 787 643	13,796,895
4·430	14·436 151 440	13,185,020	4·480	15·110 584 538	13,809,678
4·431	14·449 336 460	13,197,228	4·481	15·124 394 216	13,822,472
4·432	14·462 533 688	13,209,447	4·482	15·138 216 688	13,835,277
4·433	14·475 743 135	13,221,679	4·483	15·152 051 965	13,848,095
4·434	14·488 964 814	13,233,921	4·484	15·165 900 060	13,860,927
4·435	14·502 198 735	13,246,177	4·485	15·179 760 987	13,873,770
4·436	14·515 444 912	13,258,439	4·486	15·193 634 757	13,886,625
4·437	14·528 703 351	13,270,719	4·487	15·207 521 382	13,899,490
4·438	14·541 974 070	13,283,007	4·488	15·221 420 872	13,912,368
4·439	14·555 257 077	13,295,307	4·489	15·235 333 240	13,925,259
4·440	14·568 552 384	13,307,619	4·490	15·249 258 499	13,938,163
4·441	14·581 860 003	13,319,943	4·491	15·263 196 662	13,951,079
4·442	14·595 179 946	13,332,276	4·492	15·277 147 741	13,964,004
4·443	14·608 512 222	13,344,623	4·493	15·291 111 745	13,976,943
4·444	14·621 856 845	13,356,982	4·494	15·305 088 688	13,989,894
4·445	14·635 213 827	13,369,351	4·495	15·319 078 582	14,002,859
4·446	14·648 583 178	13,381,731	4·496	15·333 081 441	14,015,834
4·447	14·661 964 909	13,394,126	4·497	15·347 097 275	14,028,822
4·448	14·675 359 035	13,406,530	4·498	15·361 126 097	14,041,822
4·449	14·688 765 565	13,418,945	4·499	15·375 167 919	14,054,835
4·450	14·702 184 510	13,431,374	4·500	15·389 222 754	14,067,859

x	I_1x	Difference	x	I_1x	Difference
4·500	15·389 222 754	14,067,859	4·550	16·108 828 111	14,734,909
4·501	15·403 290 613	14,080,896	4·551	16·123 563 020	14,748,572
4·502	15·417 371 509	14,093,945	4·552	16·138 311 592	14,762,249
4·503	15·431 465 454	14,107,005	4·553	16·153 073 841	14,775,936
4·504	15·445 572 459	14,120,079	4·554	16·167 849 777	14,789,637
4·505	15·459 692 538	14,133,165	4·555	16·182 639 414	14,803,352
4·506	15·473 825 703	14,146,262	4·556	16·197 442 766	14,817,079
4·507	15·487 971 965	14,159,373	4·557	16·212 259 845	14,830,820
4·508	15·502 131 338	14,172,496	4·558	16·227 090 665	14,844,572
4·509	15·516 303 834	14,185,630	4·559	16·241 935 237	14,858,338
4·510	15·530 489 464	14,198,778	4·560	16·256 793 575	14,872,116
4·511	15·544 688 242	14,211,938	4·561	16·271 665 691	14,885,908
4·512	15·558 900 180	14,225,109	4·562	16·286 551 599	14,899,712
4·513	15·573 125 289	14,238,293	4·563	16·301 451 311	14,913,531
4·514	15·587 363 582	14,251,489	4·564	16·316 364 842	14,927,360
4·515	15·601 615 071	14,264,699	4·565	16·331 292 202	14,941,204
4·516	15·615 879 770	14,277,920	4·566	16·346 233 406	14,955,060
4·517	15·630 157 690	14,291,154	4·567	16·361 188 466	14,968,931
4·518	15·644 448 844	14,304,401	4·568	16·376 157 397	14,982,812
4·519	15·658 753 245	14,317,659	4·569	16·391 140 209	14,996,709
4·520	15·673 070 904	14,330,930	4·570	16·406 136 918	15,010,617
4·521	15·687 401 834	14,344,214	4·571	16·421 147 535	15,024,538
4·522	15·701 746 048	14,357,510	4·572	16·436 172 073	15,038,474
4·523	15·716 103 558	14,370,819	4·573	16·451 210 547	15,052,421
4·524	15·730 474 377	14,384,138	4·574	16·466 262 968	15,066,382
4·525	15·744 858 515	14,397,472	4·575	16·481 329 350	15,080,355
4·526	15·759 255 987	14,410,819	4·576	16·496 409 705	15,094,343
4·527	15·773 666 806	14,424,177	4·577	16·511 504 048	15,108,344
4·528	15·788 090 983	14,437,549	4·578	16·526 612 392	15,122,357
4·529	15·802 528 532	14,450,932	4·579	16·541 734 749	15,136,384
4·530	15·816 979 464	14,464,329	4·580	16·556 871 133	15,150,423
4·531	15·831 443 793	14,477,737	4·581	16·572 021 556	15,164,476
4·532	15·845 921 530	14,491,159	4·582	16·587 186 032	15,178,542
4·533	15·860 412 689	14,504,592	4·583	16·602 364 574	15,192,623
4·534	15·874 917 281	14,518,040	4·584	16·617 557 197	15,206,713
4·535	15·889 435 321	14,531,498	4·585	16·632 763 910	15,220,821
4·536	15·903 966 819	14,544,970	4·586	16·647 984 731	15,234,939
4·537	15·918 511 789	14,558,454	4·587	16·663 219 670	15,249,072
4·538	15·933 070 243	14,571,952	4·588	16·678 468 742	15,263,216
4·539	15·947 642 195	14,585,462	4·589	16·693 731 958	15,277,376
4·540	15·962 227 657	14,598,984	4·590	16·709 009 334	15,291,547
4·541	15·976 826 641	14,612,519	4·591	16·724 300 881	15,305,735
4·542	15·991 439 160	14,626,068	4·592	16·739 606 616	15,319,931
4·543	16·006 065 228	14,639,628	4·593	16·754 926 547	15,334,146
4·544	16·020 704 856	14,653,201	4·594	16·770 260 693	15,348,368
4·545	16·035 358 057	14,666,786	4·595	16·785 609 061	15,362,610
4·546	16·050 024 843	14,680,387	4·596	16·800 971 671	15,376,861
4·547	16·064 705 230	14,693,999	4·597	16·816 348 532	15,391,126
4 548	16·079 399 229	14,707,622	4·598	16·831 739 658	15,405,406
4·549	16·094 106 851	14,721,260	4·599	16·847 145 064	15,419,698
4·550	16·108 828 111	14,734,909	4·600	16·862 564 762	15,434,004

x	I_1x	Difference	x	I_1x	Difference
4·600	16·862 564 762	15,434,004	4·650	17·652 072 549	16,166,690
4·601	16·877 998 766	15,448,322	4·651	17·668 239 239	16,181,700
4·602	16·893 447 088	15,462,656	4·652	17·684 420 939	16,196,719
4·603	16·908 909 744	15,477,001	4·653	17·700 617 658	16,211,758
4·604	16·924 386 745	15,491,362	4·654	17·716 829 416	16,226,805
4·605	16·939 878 107	15,505,734	4·655	17·733 056 221	16,241,869
4·606	16·955 383 841	15,520,122	4·656	17·749 298 090	16,256,948
4·607	16·970 903 963	15,534,521	4·657	17·765 555 038	16,272,040
4·608	16·986 438 484	15,548,935	4·658	17·781 827 078	16,287,147
4·609	17·001 987 419	15,563,361	4·659	17·798 114 225	16,302,266
4·610	17·017 550 780	15,577,804	4·660	17·814 416 491	16,317,402
4·611	17·033 128 584	15,592,256	4·661	17·830 733 893	16,332,550
4·612	17·048 720 840	15,606,726	4·662	17·847 066 443	16,347,714
4·613	17·064 327 566	15,621,205	4·663	17·863 414 157	16,362,892
4·614	17·079 948 771	15,635,703	4·664	17·879 777 049	16,378,082
4·615	17·095 584 474	15,650,209	4·665	17·896 155 131	16,393,291
4·616	17·111 234 683	15,664,733	4·666	17·912 548 422	16,408,509
4·617	17·126 899 416	15,679,270	4·667	17·928 956 931	16,423,744
4·618	17·142 578 686	15,693,816	4·668	17·945 380 675	16,438,994
4·619	17·158 272 502	15,708,383	4·669	17·961 819 669	16,454,257
4·620	17·173 980 885	15,722,958	4·670	17·978 273 926	16,469,532
4·621	17·189 703 843	15,737,549	4·671	17·994 743 458	16,484,827
4·622	17·205 441 392	15,752,152	4·672	18·011 228 285	16,500,132
4·623	17·221 193 544	15,766,771	4·673	18·027 728 417	16,515,452
4·624	17·236 960 315	15,781,403	4·674	18·044 243 869	16.530,788
4·625	17·252 741 718	15,796,049	4·675	18·060 774 657	16,546,138
4·626	17·268 537 767	15,810,706	4·676	18·077 320 795	16,561,502
4·627	17·284 348 473	15,825,382	4·677	18·093 882 297	16,576,879
4·628	17·300 173 855	15,840,068	4·678	18·110 459 176	16,592,274
4·629	17·316 013 923	15,854,767	4·679	18·127 051 450	16,607,678
4·630	17·331 868 690	15,869,483	4·680	18·143 659 128	16,623,103
4·631	17·347 738 173	15,884,212	4·681	18·160 282 231	16,638.537
4·632	17·363 622 385	15,898,953	4·682	18·176 920 768	16,653,990
4·633	17·379 521 338	15,913,710	4·683	18·193 574 758	16,669,453
4·634	17·395 435 048	15,928,478	4·684	18·210 244 211	16,684,934
4·635	17·411 363 526	15,943,262	4·685	18·226 929 145	16,700,427
4·636	17·427 306 788	15,958,061	4·686	18·243 629 572	16,715,938
4·637	17·443 264 849	15,972,870	4·687	18·260 345 510	16,731,460
4·638	17·459 237 719	15,987,698	4·688	18·277 076 970	16,746,998
4·639	17·475 225 417	16,002,536	4·689	18·293 823 968	16,762,552
4·640	17·491 227 953	16,017,390	4·690	18·310 586 520	16,778,118
4·641	17·507 245 343	16,032,255	4·691	18·327 364 638	16,793,700
4·642	17·523 277 598	16,047,139	4·692	18·344 158 338	16,809,297
4·643	17·539 324 737	16,062,032	4·693	18·360 967 635	16,824,908
4·644	17·555 386 769	16,076,943	4·694	18·377 792 543	16,840,533
4·645	17·571 463 712	16,091,863	4·695	18·394 633 076	16,856,175
4·646	17·587 555 575	16,106,804	4·696	18·411 489 251	16,871,829
4·647	17·603 662 379	16,121,753	4·697	18·428 361 080	16,887,499
4·648	17·619 784 132	16,136,718	4·698	18·445 248 579	16,903,185
4·649	17·635 920 850	16,151,699	4·699	18·462 151 764	16,918,883
4·650	17·652 072 549	16,166,690	4·700	18·479 070 647	16,934,598

x	I_1x	Difference	x	I_1x	Difference
4·700	18·479 070 647	16,934,598	4·750	19·345 361 448	17,739,429
4·701	18·496 005 245	16,950,327	4·751	19·363 100 877	17,755,913
4·702	18·512 955 572	16,966,071	4·752	19·380 856 790	17,772,415
4·703	18·529 921 643	16,981,829	4·753	19·398 629 205	17,788,932
4·704	18·546 903 472	16,997,604	4·754	19·416 418 137	17,805,464
4·705	18·563 901 076	17,013,390	4·755	19·434 223 601	17,822,010
4·706	18·580 914 466	17,029,194	4·756	19·452 045 611	17,838,573
4·707	18·597 943 660	17,045,011	4·757	19·469 884 184	17,855,152
4·708	18·614 988 671	17,060,844	4·758	19·487 739 336	17,871,747
4·709	18·632 049 515	17,076,692	4·759	19·505 611 083	17,888,356
4·710	18·649 126 207	17,092,556	4·760	19·523 499 439	17,904,980
4·711	18·666 218 763	17,108,430	4·761	19·541 404 419	17,921,623
4·712	18·683 327 193	17,124,324	4·762	19·559 326 042	17,938,279
4·713	18·700 451 517	17,140,233	4·763	19·577 264 321	17,954,953
3·714	18·717 591 750	17,156,152	4·764	19·595 219 274	17,971,638
4·715	18·734 747 902	17,172,090	4·765	19·613 190 912	17,988,343
4·716	18·751 919 992	17,188,043	4·766	19·631 179 255	18,005,063
4·717	18·769 108 035	17,204,008	4·767	19·649 184 318	18,021,798
4·718	18·786 312 043	17,219,992	4·768	19·667 206 116	18,038,547
4·719	18·803 532 035	17,235,990	4·769	19·685 244 663	18,055,314
4·720	18·820 768 025	17,252,001	4·770	19·703 299 977	18,072,098
4·721	18·838 020 026	17,268,028	4·771	19·721 372 075	18,088,895
4·722	18·855 288 054	17,284,070	5·772	19·739 460 970	18,105,710
4·723	18·872 572 124	17,300,128	4·773	19·757 566 680	18,122,538
4·724	18·889 872 252	17,316,200	4·774	19·775 689 218	18,139,386
4·725	18·907 188 452	17,332,288	4·775	19·793 828 604	18,156,245
4·726	18·924 520 740	17,348,391	4·776	19·811 984 849	18,173,123
4·727	18·941 869 131	17,364,509	4·777	19·830 157 972	18,190,016
4·728	18·959 233 640	17,380,642	4·778	19·848 347 988	18,206,926
4·729	18·976 614 282	17,396,788	4·779	19·866 554 914	18,223,849
4·730	18·994 011 070	17,412,954	4·780	19·884 778 763	18,240,790
4·731	19·011 424 024	17,429,132	4·781	19·903 019 553	18,257,748
4·732	19·028 853 156	17,445,325	4·782	19·921 277 301	18,274,720
4·733	19·046 298 481	17,461,534	4·783	19·939 552 021	18,291,709
4·734	19·063 760 015	17,477,758	4·784	19·957 843 730	18,308,713
4·735	19·081 237 773	17,493,998	4·785	19·976 152 443	18,325,735
5·736	19·098 731 771	17,510,253	4·786	19·994 478 178	18,342,769
4·737	19·116 242 024	17,526,520	4·787	20·012 820 947	18,359,823
4·738	19·133 768 544	17,542,808	4·788	20·031 180 770	18,376,892
4·739	19·151 311 352	17,559,108	4·789	20·049 557 662	18,393,976
4·740	19·168 870 460	17,575,424	4·790	20·067 951 638	18,411,078
4·741	19·186 445 884	17,591,755	4·791	20·086 362 716	18,428,194
4·742	19·204 037 639	17,608,102	4·792	20·104 790 910	18,445,327
4·743	19·221 645 741	17,624,463	4·793	20·123 236 237	18,462,475
4·744	19·239 270 204	17,640,841	4·794	20·141 698 712	18,479,641
4·745	19·256 911 045	17,657,233	4·795	20·160 178 353	18,496,822
4·746	19·274 568 278	17,673,642	4·796	20·178 675 175	18,514,020
4·747	19·292 241 920	17,690,065	4·797	20·197 189 195	18,531,233
4·748	19·309 931 985	17,706,505	4·798	20·215 720 428	18,548,463
4·749	19·327 638 490	17,722,958	4·799	20·234 268 891	18,565,709
4·750	19·345 361 448	17,739,429	4·800	20·252 834 600	18,582,971

x	I_1x	Difference	x	I_1x	Difference
4·800	20·252 834 600	18,582,971	4·850	21·203 471 276	19,467,100
4·801	20·271 417 571	18,600,251	4·851	21·222 938 376	19,485,211
4·802	20·290 017 822	18,617,543	4·852	21·242 423 587	19,503,339
4·803	20·308 635 365	18,634,856	4·853	21·261 926 926	19,521,482
4·804	20·327 270 221	18,652,182	4·854	21·281 448 408	19,539,643
4·805	20·345 922 403	18,669,527	4·855	21·300 988 051	19,557,821
4·806	20·364 591 930	18,686,885	4·856	21·320 545 872	19,576,017
4·807	20·383 278 815	18,704,263	5·857	21·340 121 889	19,594,228
4·808	20·401 983 078	18,721,654	4·858	21·359 716 117	19,612,459
4·809	20·420 704 732	18,739,064	4·859	21·379 328 576	19,630,706
4·810	20·439 443 796	18,756,488	4·860	21·398 959 282	19,648,968
4·811	20·458 200 284	18,773,930	4·861	21·418 608 250	19,667,250
4·812	20·476 974 214	18,791,389	4·862	21·438 275 500	19,685,548
4·813	20·495 765 603	18,808,863	4·863	21·457 961 048	19,703,863
4·814	20·514 574 466	18,826,353	4·864	21·477 664 911	19,722,198
4·815	20·533 400 819	18,843,861	4·865	21·497 387 109	19,740,546
4·816	20·552 244 680	18,861,385	4·866	21·517 127 655	19,758,914
4·817	20·571 106 065	18,878,924	4·867	21·536 886 569	19,777,297
4·818	20·589 984 989	18,896,482	4·868	21·556 663 866	19,795,700
4·819	20·608 881 471	18,914,054	4·869	21·576 459 566	19,814,118
4·820	20·627 795 525	18,931,645	4·870	21·596 273 684	19,832,554
4·821	20·646 727 170	18,949,252	4·871	21·616 106 238	19,851,008
4·822	20·665 676 422	18,966,874	4·872	21·635 957 246	19,869,481
4·823	20·684 643 296	18,984,513	4·873	21·655 826 727	19,887,967
4·824	20·703 627 809	19,002,169	4·874	21·675 714 694	19,906,474
4·825	20·722 629 978	19,019,842	4·875	21·695 621 168	19,924,998
4·826	20·741 649 820	19,037,532	4·876	21·715 546 166	19,943,538
4·827	20·760 687 352	19,055,238	4·877	21·735 489 704	19,962,094
4·828	20·779 742 590	19,072,959	4·878	21·755 451 798	19,980,672
4·829	20·798 815 549	19,090,700	4·879	21·775 432 470	19,999,265
4·830	20·817 906 249	19,108,454	4·880	21·795 431 735	20,017,874
4·831	20·837 014 703	19,126,227	4·881	21·815 449 609	20,036,504
4·832	20·856 140 930	19,144,018	4·882	21·835 486 113	20,055,150
4·833	20·875 284 948	19,161,823	4·883	21·855 541 263	20,073,811
4·834	20·894 446 771	19,179,645	4·884	21·875 615 074	20,092,492
4·835	20·913 626 416	19,197,486	4·885	21·895 707 566	20,111,190
4·836	20·932 823 902	19,215,341	4·886	21·915 818 756	20,129,907
4·837	20·952 039 243	19,233,215	4·887	21·935 948 663	20,148,640
4·838	20·971 272 458	19,251,105	4·888	21·956 097 303	20,167,390
4·839	20·990 523 563	19,269,010	4·889	21·976 264 693	20,186,160
4·840	21·009 792 573	19,286,936	4·890	21·996 450 853	20,204,946
4·841	21·029 079 509	19,304,877	4·891	22·016 655 799	20,223,750
4·842	21·048 384 386	19,322,832	4·892	22·036 879 549	20,242,571
4·843	21·067 707 218	19,340,807	4·893	22·057 122 120	20,261,410
4·844	21·087 048 025	19,358,798	4·894	22·077 383 530	20,280,270
4·845	21·106 406 823	19,376,808	4·895	22·097 663 800	20,299,144
4·846	21·125 783 631	19,394,830	4·896	22·117 962 944	20,318,035
4·847	21·145 178 461	19,412,873	4·897	22·138 280 979	20,336,947
4·848	21·164 591 334	19,430,933	4·898	22·158 617 926	20,355,873
4·849	21·184 022 267	19,449,009	4·899	22·178 973 799	20,374,821
4·850	21·203 471 276	19,467,100	4·900	22·199 348 620	20,393,787

x	I_1x	Difference	x	I_1x	Difference
4·900	22·199 348 620	20,393,787	4·950	23·242 644 448	21,365,085
4·901	22·219 742 407	20,412,766	4·951	23·264 009 533	21,384,979
4·902	22·240 155 173	20,431,765	4·952	23·285 394 512	21,404,895
4·903	22·260 586 938	20,450,783	4·953	23·306 799 407	21,424,830
4·904	22·281 037 721	20,469,820	4·954	23·328 224 237	21,444,778
4·905	22·301 507 541	20,488,873	4·955	23·349 669 015	21,464,753
4·906	22·321 996 414	20,507,943	4·956	23·371 133 768	21,484,739
4·907	22·342 504 357	20,527,032	4·957	23·392 618 507	21,504,749
4·908	22·363 031 389	20,546,139	4·958	23·414 123 256	21,524,777
4·909	22·383 577 528	20,565,265	4·959	23·435 648 033	21,544,821
4·910	22·404 142 793	20,584,410	4·960	23·457 192 854	21,564,887
4·911	22·424 727 203	20,603,568	4·961	23·478 757 741	21,584,971
4·912	22·445 330 771	20,622,747	4·962	23·500 342 712	21,605,073
4·913	22·465 953 518	20,641,945	4·963	23·521 947 785	21,625,196
4·914	22·486 595 463	20,661,161	4·964	23·543 572 981	21,645,335
4·915	22·507 256 624	20,680,393	4·965	23·565 218 316	21,665,496
4·916	22·527 937 017	20,699,644	4·966	23·586 883 812	21,685,674
4·917	22·548 636 661	20,718,915	4·967	23·608 569 486	21,705,871
4·918	22·569 355 576	20,738,202	4·968	23·630 275 357	21,726,090
4·919	22·590 093 778	20,757,508	4·969	23·652 001 447	21,746,322
4·920	22·610 851 286	20,776,833	4·970	23·673 747 769	21,766,579
4·921	22·631 628 119	20,796,174	4·971	23·695 514 348	21,786,851
4·922	22 652 424 293	20,815,533	4·972	23·717 301 199	21,807,145
4·923	22·673 239 826	20,834,914	4·973	23·739 108 344	21,827,457
4·924	22·694 074 740	20,854,310	4·974	23·760 935 801	21,847,787
4·925	22·714 929 050	20,873,723	4·975	23·782 783 588	21,868,138
4·926	22·735 802 773	20,893,159	4·976	23·804 651 726	21,888,507
4·927	22·756 695 932	20,912,609	4·977	23·826 540 233	21,908,893
4·928	22·777 608 541	20,932,080	4·978	23·848 449 126	21,929,304
4·929	22·798 540 621	20,951,568	4·979	23·870 378 430	21,949,730
4·930	22·819 492 189	20,971,075	4·980	23·892 328 160	21,970,176
4·931	22·840 463 264	20,990,599	4·981	23·914 298 336	21,990,642
4·932	22·861 453 863	21,010,143	4·982	23·936 288 978	22,011,125
4·933	22·882 464 006	21,029,703	4·983	23·958 300 103	22,031,630
4·934	22·903 493 709	21,049,286	4·984	23·980 331 733	22,052,152
4·935	22·924 542 995	21,068,883	4·985	24·002 383 885	22,072,695
4·936	22·945 611 878	21,088,500	4·986	24·024 456 580	22,093,258
4·937	22·966 700 378	21,108,135	4·987	24·046 549 838	22,113,838
4·938	22·987 808 513	21,127,790	4·988	24·068 663 676	22,134,440
4·939	23·008 936 303	21,147,461	4·989	24·090 798 116	22,155,058
4·940	23·030 083 764	21,167,153	4·990	24·112 953 174	22,175,698
4·941	23·051 250 917	21,186,863	4·991	24·135 128 872	22,196,358
4·942	23·072 437 780	21,206,590	4·992	24·157 325 230	22,217,035
4·943	23·093 644 370	21,226,337	4·993	24·179 542 265	22,237,734
4·944	23·114 870 707	21,246,103	4·994	24·201 779 999	22,258,450
4·945	23·136 116 810	21,265,886	4·995	24·224 038 449	22,279,187
4·946	23·157 382 696	21,285,687	4·996	24·246 317 636	22,299,944
4·947	23·178 668 383	21,305,510	4·997	24·268 617 580	22,320,718
4·948	23·199 973 893	21,325,349	4·998	24·290 938 298	22,341,516
4·949	23·221 299 242	21,345,206	4·999	24·313 279 814	22,362,328
4·950	23·242 644 448	21,365,085	5·000	24·335 642 142	22,383,164

x	I_1x	Difference	x	I_1x	Difference
5·000	24·335 642 142	22,383,164	5·050	25·480 735 808	23,450,292
5·001	24·358 025 306	22,404,018	5·051	25·504 186 100	23,472,151
5·002	24·380 429 324	22,424,892	5·052	25·527 658 251	23,494,030
5·003	24·402 854 216	22,445,786	5·053	25·551 152 281	23,515,931
5·004	24·425 300 002	22,466,697	5·054	25·574 668 212	23,537,852
5·005	24·447 766 699	22,487,632	5·055	25·598 206 064	23,559,793
5·006	24·470 254 331	22,508,584	5·056	25·621 765 857	23,581,755
5·007	24·492 762 915	22,529,555	5·057	25·645 347 612	23,603,736
5·008	24·515 292 470	22,550,548	5·058	25·668 951 348	23,625,741
5·009	24·537 843 018	22,571,560	5·059	25·692 577 089	23,647,765
5·010	24·560 414 578	22,592,590	5·060	25·716 224 854	23,669,811
5·011	24·583 007 168	22,613,644	5·061	25·739 894 665	23,691,876
5·012	24·605 620 812	22,634,712	5·062	25·763 586 541	23,713,963
5·013	24·628 255 524	22,655,806	5·063	25·787 300 504	23,736,070
5·014	24·650 911 330	22,676,915	5·064	25·811 036 574	23,758,197
5·015	24·673 588 245	22,698,046	5·065	25·834 794 771	23,780,348
5·016	24·696 286 291	22,719,196	5·066	25·858 575 119	23,802,515
5·017	24·719 005 487	22,740,367	5·067	25·882 377 634	23,824,709
5·018	24·741 745 854	22,761,558	5·068	25·906 202 343	23,846,917
5·019	24·764 507 412	22,782,768	5·069	25·930 049 260	23,869,153
5·020	24·787 290 180	22,803,998	5·070	25·953 918 413	23,891,404
5·021	24·810 094 178	22,825,250	5·071	25·977 809 817	23,913,680
5·022	24·832 919 428	22,846,519	5·072	26·001 723 497	23,935,977
5·023	24·855 765 947	22,867,809	5·073	26·025 659 474	23,958,291
5·024	24·878 633 756	22,889,120	5·074	26·049 617 765	23,980,629
5·025	24·901 522 876	22,910,451	5·075	26·073 598 394	24,002,986
5·026	24·924 433 327	22,931,801	5·076	26·097 601 380	24,025,368
5·027	24·947 365 128	22,953,173	5·077	26·121 626 748	24,047,767
5·028	24·970 318 301	22,974,561	5·078	26·145 674 515	24,070,190
5·029	24·993 292 862	22,995,975	5·079	26·169 744 705	24,092,631
5·030	25·016 288 837	23,017,404	5·080	26·193 837 336	24,115,096
5·031	25·039 306 241	23,038,856	5·081	26·217 952 432	24,137,582
5·032	25·062 345 097	23,060,329	5·082	26·242 090 014	24,160,089
5·033	25·085 405 426	23,081,818	5·083	26·266 250 103	24,182,614
5·034	25·108 487 244	23,103,332	5·084	26·290 432 717	24,205,165
5·035	25·131 590 576	23,124,865	5·085	26·314 637 882	24,227,733
5·036	25·154 715 441	23,146,416	5·086	26·338 865 615	24,250,325
5·037	25·177 861 857	23,167,989	5·087	26·363 115 940	24,272,937
5·038	25·201 029 846	23,189,581	5·088	26·387 388 877	24,295,572
5·039	25·224 219 427	23,211,197	5·089	26·411 684 449	24,318,226
5·040	25·247 430 624	23,232,829	5·090	26·436 002 675	24,340,903
5·041	25·270 663 453	23,254,483	5·091	26·460 343 578	24,363,601
5·042	25·293 917 936	23,276,159	5·092	26·484 707 179	24,386,322
5·043	25·317 194 095	23,297,853	5·093	26·509 093 501	24,409,059
5·044	25·340 491 948	23,319,569	5·094	26·533 502 560	24,431,823
5·045	25·363 811 517	23,341,304	5·095	26·557 934 383	24,454,608
5·046	25·387 152 821	23,363,062	5·096	26·582 388 991	24,477,409
5·047	25·410 515 883	23,384,837	5·097	26·606 866 400	24,500,239
5·048	25·433 900 720	23,406,635	5·098	26·631 366 639	24,523,084
5·049	25·457 307 355	23,428,453	5·099	26·655 889 723	24,545,957
5·050	25·480 735 808	23,450,292	5·100	26·680 435 680	

Meteorological Observations on Ben Nevis.—Report of the Committee, consisting of Lord McLaren (*Chairman*), Professor A. Crum Brown (*Secretary*), Dr. John Murray, Dr. Alexander Buchan, Hon. Ralph Abercrombie, *and* Professor R. Copeland. (*Drawn up by* Dr. Buchan.)

The Committee were appointed as in former years for the purpose of co-operating with the Scottish Meteorological Society in making meteorological observations on Ben Nevis.

The hourly eye-observations by night and by day have been made during the past year at the Ben Nevis Observatory without a single interruption by Mr. Omond and his assistants; also the continuous registrations and other observations have been carried on at the Low Level Observatory at Fort William with the same fulness of detail as during the previous two years.

The Directors of the observatories tender their cordial thanks to Messrs. R. C. Mossman, F.R.S.E., A. J. Herbertson, C. Stewart, B.Sc., J. I. Craig, and A. Shand for valuable assistance rendered as volunteer observers during the winter and summer for periods varying from four to ten weeks, thus affording much needed relief to the members of the regular observing staff.

For the year 1892 Table I. shows the monthly mean and extreme pressures, temperatures, hours of sunshine, amounts of rainfall, number of fair days or days of less than 0·01 inch of rain, at the observatories, the mean pressures at the top of the Ben being reduced to 32° only, while those at Fort William are reduced to 32° and sea-level (see Table I.).

The mean temperature of the whole year at Fort William was 45°·3, being 1°·9 less than the mean of previous years, being nearly the deficiency for 1892 of a large part of Scotland to the north and east of Fort William. The mean temperature at the top of Ben Nevis was 29°·7, which is 1°·1 under the mean. Thus the mean temperature at the top, as compared with the foot of the mountain, was 0°·8 relatively warmer, and this relatively higher temperature was maintained at all strictly island and sea-coast situations from Monach in the Outer Hebrides to Corsewall Point, Wigtownshire, just as occurred in 1891. The difference was occasioned chiefly by the temperatures of the spring months and December.

The lowest mean monthly temperature at Fort William was 35°·3 in December, being 4°·6 under the mean; but at the top of the Ben 20°·3 in March, being 2°·3 under the mean. At the top the mean for December was 24°·0, being only 0°·7 under the average; whilst, as stated above, the mean of Fort William was 4°·6 under the average. The difference of the means of the two observatories was only 11°·3, instead of the normal 15°·2. This remarkably higher relative temperature of the top in December was altogether due to the prevalence of well-marked anticyclones during the time, when the temperature at the top was frequently much higher than at Fort William. It was during these periods, when extraordinary dryness of the air also prevails, that Mr. Herbertson succeeded in obtaining the most valuable of the hygrometric observations in connection with the large inquiry he is now conducting at the two

TABLE I.

1892	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
						Mean Pressure in Inches.							
Ben Nevis Observatory	25·096	25·140	25·362	25·395	25·346	25·398	25·471	25·301	25·234	25·146	25·281	25·235	25·284
Fort William	29·717	29·755	30·034	29·995	29·894	29·922	29·969	29·772	29·744	29·707	29·849	29·862	29·852
Differences .	4·621	4·615	4·672	4·600	4·548	4·524	4·498	4·471	4·510	4·561	4·568	4·627	4·568
						Mean Temperatures.							
Ben Nevis Observatory	21°·8	22°·6	20°·3	27°·9	33°·0	35°·9	40°·7	39°·1	34°·4	27°·2	29°·8	24°·0	29°·7
Fort William	37·7	37·8	36·5	43·2	49·6	53·0	55·6	55·3	50·3	43·4	45·0	35·8	45·3
Differences .	15·9	15·2	16·2	15·3	16·6	17·1	14·9	16·2	15·9	16·2	15·2	11·8	15·6
						Extremes of Temperature, Maxima.							
Ben Nevis Observatory	37°·2	40°·1	39°·3	44°·1	44°·3	56°·0	59°·1	50°·7	47°·3	38°·2	42°·9	37°·5	59°·1
Fort William	53·9	49·2	57·0	65·8	67·7	75·5	72·8	68·4	60·0	52·5	54·7	51·8	75·5
Differences .	16·7	9·1	17·7	21·7	23·4	19·5	13·7	17·7	12·7	14·3	11·8	14·3	16·4
						Extremes of Temperature, Minima.							
Ben Nevis Observatory	8°·8	7°·0	3°·5	11°·5	20°·4	22°·9	29°·8	28°·0	25°·1	16°·2	16°·2	10°·9	3°·5
Fort William	17·0	13·3	20·1	23·0	32·6	37·2	43·9	41·3	34·7	23·3	30·0	17·9	13·3
Differences .	8·2	6·3	16·6	11·5	12·2	14·3	14·1	13·3	9·6	7·1	13·8	7·0	9·8
						Rainfall in Inches.							
Ben Nevis Observatory	22·32	12·30	5·42	5·91	14·07	9·56	10·83	15·47	21·90	9·53	13·86	9·73	150·90
Fort William	8·54	2·93	1·84	1·96	5·97	3·87	5·47	8·14	14·43	5·35	9·39	5·39	73·28
Differences .	13·78	9·37	3·58	3·95	8·10	5·69	5·36	7·33	7·47	4·18	4·47	4·34	77·62
						Number of Days of no Rain.							
Ben Nevis Observatory	5	10	14	10	6	8	16	9	12	9	7	10	116
Fort William	5	16	23	17	9	13	18	11	6	14	8	12	152
						Number of Days 1 in. or more fell.							
Ben Nevis Observatory	6	3	1	1	5	3	6	6	9	2	5	3	50
Fort William	2	1	0	0	1	0	0	2	5	0	1	1	13
						Hours of Sunshine.							
Ben Nevis Observatory	12	43	105	125	117	104	130	37	31	43	19	36	802
Fort William	24	65	136	178	168	160	160	96	74	74	25	19	1,179
Differences .	12	22	31	53	51	56	30	59	43	31	6	−17	377

observatories. The highest monthly mean temperature at the top was 40°·7 in July, and 55°·5 at Fort William in the same month, these being respectively 0°·6 above and 1°·8 under the several averages.

The maximum temperature at the top was 59°·1 on July 29, and 75°·5 at Fort William on June 6. The minimum temperature at the top was 3°·5 on March 27 from the hourly eye-observations, and 2°·7 from the minimum thermometer. This is absolutely the lowest temperature that has occurred since the opening of the observatory in 1883, and it was observed at 6 A.M. At Fort William the minimum temperature for 1892 was 13°·3 on February 19

The registrations of the sunshine-recorder show 802 hours out of a possible 4,470 hours, being 106 fewer than during the previous year.

The maximum was 130 hours in July, being the highest for July hitherto recorded, and the minimum, 12, in January. At Fort William the number for the year was 1,179 hours, or 377 in excess of the number registered on the top; a difference above the average. The greatest number was 178 hours in April, and the least 19 hours in December.

Since, at the top of Ben Nevis, the horizon is virtually clear all round, the total possible hours of sunshine agree with the theoretic number for the latitude. But at Fort William, owing to the surrounding hills, the theoretic number differs widely from the actual number possible to be observed. During the last three years Mr. Omond has observed the actual intervals between sunrise and sunset at the lower station with the following result:—

TABLE II.—*Theoretical Number of Hours of Sunshine.*

	Ben Nevis	Fort William	Difference
January	231	151	80
February	275	193	82
March	365	295	70
April	426	350	76
May	508	413	95
June	529	438	91
July	528	429	99
August	467	380	87
September	381	315	66
October	319	241	78
November	242	167	75
December	210	125	85
Year	4,481	3,497	984

Thus the summit station has 984 hours more possible sunshine than the low level: while 34 per cent. of the possible sunshine was registered by the sunshine-recorder at Fort William, 18 per cent. was registered at the top of Ben Nevis, or about half the per cent. recorded near sea-level at Fort William.

TABLE III.—*Hygrometric Readings for each Month.*

—	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Dry Bulb	15°·5	11°·0	19°·5	19°·7	30°·3	28°·3	51°·3	38°·0	46°·2	29°·0	33°·9	25°·1
Wet Bulb	12·1	6·9	14·3	17·3	21·3	25·0	36·5	31·0	31·6	23·7	26·0	16·9
Dew-point	−14·6	−25·1	−23·7	−0·3	−6·6	11·8	21·2	21·2	15·5	4·5	11·8	−27·8
Elastic Force	0·021	0·012	0·013	0·043	0·031	0·073	0·114	0·114	0·088	0·053	0·073	0·010
Relative Humidity Saturation = 100	24	17	12	35	18	47	30	50	28	33	37	7

Of these relative humidities the lowest, 7, occurred at 3 P.M. of December 24, and from 3 A.M. of the 24th to 10 A.M. of the 28th of that month the humidity did not exceed 20. At the time of lowest humidity the calculated dew-point fell to −27°·8. Each month, from December to May, the dew-point fell below the zero of Fahrenheit's scale.

The rainfall for the year was 150·90 inches, being 27·12 inches less than in 1891, and 47·44 inches less than in 1890. At Fort William the amount was 73·28 inches, or less than half of what fell at the top of the Ben. These amounts are in each case very near their averages. Mr. Omond has com-

pared the rainfall at the Fort William Observatory with the monthly amounts collected with the old gauge at Mr. Livingston's during the year and a half ending with December 1892, with the result that the rainfall at the observatory is 4·6 per cent. less than at Mr. Livingston's. The largest rainfall of any month at the top was 22·32 inches in January, and at Fort William 14·42 inches in September, the smallest amounts being respectively 5·42 inches and 1·84 inch, both occurring in March. The heaviest fall on any single day at the top was 5·76 inches on January 25, and at Fort William 2·83 inches on November 28.

The number of days on which the rainfall was *nil*, or less than one-hundredth of an inch, was 116 at the top, and 152 at Fort William. At the top the largest number of days was 16 in July, and the smallest, 5, in January; and at Fort William the numbers were 23 in March and 5 in January. At Fort William a fall of an inch of rain a day or more occurred on 13 days during 1892, but at the top of Ben Nevis on 50 days, or nearly four times as often. From one to nine such wet days were recorded at the top each month, whereas at Fort William no such wet days occurred in March, April, June, July, and September, and on four of the other months only one day each.

At Fort William the mean atmospheric pressure at 32° and sea-level was 29·852 inches, and at the top 25·284 inches, thus giving a difference of 4·568 inches. The lowest pressure at the top for the year was 24·147 inches at 2 P.M. of February 2, and the highest 25·960 inches at 7 P.M. of March 22, the difference being 1·813 inch.

Mr. A. J. Herbertson is carrying on at the two observatories the research on the hygrometry of the atmosphere referred to in our report of last year. During last autumn and early winter he spent upwards of four months at the Ben Nevis Observatory, and there measured the aqueous vapour by direct weighing, obtaining a new and valuable series of experiments at very low temperatures and humidities. Since July last a similar set of experiments are being conducted by him and two skilled assistants, involving measurements of the aqueous vapour simultaneously at both high- and low-level observatories. Observations are made at the same times with the dry and wet bulb, both in a Stevenson screen and in an Assmann aspirator psychrometer; with Regnault's hygrometer; and of the numbers of dust particles present, the general weather conditions as to barometric pressure, sunshine, wind, &c. Mr. Herbertson has communicated a preliminary report on the results of last year's observations and experiments to the Royal Society of Edinburgh, in which among other points of interest the very unsatisfactory character of the hygrometric tables now in use is clearly shown for low temperatures and great dryness. The experiments at present in progress give the corresponding data for summer temperatures and humidities; and, seeing they are conducted simultaneously both on the top of the Ben and at Fort William, the effect of large differences of pressure will be seen on the relations of the dry and wet bulb readings to the amounts of aqueous vapour actually present in the air at the time. The Directors regard these experiments as of great importance, not only as furnishing data towards a better knowledge of the hygrometry of the atmosphere, but also as leading to much needed improvements in the methods of reducing the readings of the dry and wet bulb thermometers.

Mr. Omond has written a paper on hourly readings of a black bulb thermometer *in vacuo* as compared with the readings of the dry bulb

thermometer in the Stevenson screen, which was published in the last 'Journal' of the Scottish Meteorological Society. The results are interesting and suggestive. He has prepared a paper on the height of the lower edge of the cloud layer on Ben Nevis, based on observations taken at Inverlochy during some months of the present summer; and has also instituted a comparison of the temperature observations from August 1890 to December 1891, made simultaneously by himself at the new observatory and by Mr. Livingston at the old station with the instruments in use there since 1883.

At last year's Meeting of the Association a grant of 50*l.* was made to aid in the payment of assistants to perform the strictly routine work of Dr. Buchan and Mr. Omond, so that their time would be set free for the discussion of the observations of the two observatories beginning with August 1890. This arrangement has been carried out, and the following is a detailed statement of the work which has been completed or is still in progress.

From the first eight years' observations of the rainfall at the top of Ben Nevis the mean hourly variations for the twelve months of the year have been calculated, and the hourly values reduced to percentages above or below the monthly means. The results were then 'bloxamed' in the usual way, that is, the value for 1 A.M. of January equals $\frac{XII+I+II}{3}$; for 1 A.M. of February $\frac{I+II+III}{3}$, &c., where the Roman numerals represent the values of the months December, January, February, &c., for these years. In this way Table IV. has been constructed, which shows the diurnal variation in the precipitation throughout the year. As was to have been expected, the curves for the warmer months of the year are best marked. These show a clearly defined double maximum and minimum. The larger maximum occurs from 11 A.M. to 8 P.M., or during the warmer hours of the day after the ascending current has set in. Then a minimum occurs from 8 P.M. to 1 A.M., or during the hours when temperature falls most rapidly, and the evening maximum of pressure prevails. For the next six hours precipitation is above the average, the greatest increase being from 5 to 6 A.M.; and finally from 7 to 11 A.M. the next minimum occurs, or during the hours atmospheric pressure and temperature increase, and terminates with the formation of the ascending current, which is so pronounced a feature in the meteorology of Ben Nevis. During the colder months the curves are less distinctly marked, except a decided maximum during the coldest hours of the day, and a minimum during the hours of the morning barometric maximum, when temperature is rising.

The hourly variation of the rainfall is more clearly shown than at any other observatory at which hourly observations have been made from results extending over a comparatively short term of years.

The discussion of the hourly barometric and thermometric means at the two observatories for the three years is nearly complete.

An inquiry into the diurnal variation of the barometer and thermometer on Ben Nevis during days of clear weather on the one hand, and days of fog or mist throughout on the other, is completed for the three years ending August 1893. The inquiry had not proceeded far when it was apparent that the curves for clear weather and those for clouded weather while fog or mist was absent were in all essential respects the same; but the curves were of quite a different character when fog or mist prevailed.

TABLE IV.—*Showing the Hourly Variation of the Rainfall on Ben Nevis, expressed in Percentages above or below the daily means.*

For Hour ending	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+ 1	− 3	− 2	− 6	−11	−14	−10	− 3	+ 2	+ 5	+ 7	+ 4	—
2 "	+ 6	+ 5	+ 2	+ 2	+ 2	− 1	+ 4	− 2	+ 3	+ 1	+ 8	+ 9	—
3 "	+12	+ 9	+ 7	+ 1	− 3	− 6	+ 2	+ 3	+ 5	+ 4	+10	+13	—
4 "	+ 0	+ 3	+ 0	+ 8	+ 3	+ 2	+ 0	+ 5	+ 3	− 1	− 3	+ 3	—
5 "	+ 8	+18	+12	+ 6	− 3	− 2	− 1	+ 1	+ 7	+ 5	+ 3	+ 1	—
6 "	+ 0	+12	+18	+20	+11	+11	+14	+ 8	+ 2	− 3	+ 0	+ 0	—
7 "	− 9	− 2	+ 9	+ 8	+ 3	− 3	+ 1	− 1	− 9	−13	−13	−10	—
8 "	− 5	− 5	− 5	− 9	−15	−13	−11	− 7	−12	− 5	− 2	− 0	—
9 "	− 3	− 7	− 9	−12	−17	−12	−12	− 5	− 5	− 0	+ 0	− 2	—
10 "	+ 4	+ 1	− 5	−10	−13	−12	−11	− 1	+ 0	+ 4	+ 1	+ 4	—
11 "	+ 6	+ 2	+ 4	− 5	− 8	− 4	− 5	+ 8	+ 2	− 1	− 7	− 6	—
Noon	+ 3	− 7	− 1	+ 5	+11	+12	+ 2	+ 1	− 3	− 1	+ 4	+ 0	—
1 P.M.	+ 1	+ 1	+ 2	+ 4	+ 7	+10	+ 8	+ 6	+10	+12	+11	+ 3	—
2 "	− 2	− 4	− 3	+ 3	+13	+10	+ 6	+ 1	+ 2	+ 1	− 2	− 1	—
3 "	− 3	+ 0	− 9	+ 0	+15	+20	+14	− 1	+ 1	− 5	− 8	− 5	—
4 "	+ 0	+ 2	− 2	+ 0	+ 5	+ 6	+ 7	+ 3	+ 4	− 1	− 5	− 2	—
5 "	+ 1	+ 1	− 4	+ 2	+11	+11	+ 7	+ 7	+ 3	− 4	+ 2	+ 3	—
6 "	− 5	−11	− 5	+ 6	+16	+13	+11	+ 4	+ 5	+ 0	+ 3	− 2	—
7 "	− 5	− 1	− 5	− 1	+ 1	+ 4	+ 1	+ 0	− 1	− 1	− 6	− 4	—
8 "	+ 2	− 1	+ 6	+ 2	+ 6	+ 7	+ 5	+ 1	− 4	− 6	− 5	− 6	—
9 "	+ 7	− 1	− 2	− 5	− 5	− 8	− 3	− 1	− 2	− 3	+ 2	+ 7	—
10 "	+ 2	+ 3	+ 5	− 2	−10	−13	−14	− 7	− 5	+ 3	+ 3	+ 3	—
11 "	− 7	− 8	−11	−16	−18	−13	−12	− 5	− 2	+ 2	− 4	− 7	—
Midnight	−11	− 7	− 3	− 3	− 3	− 6	− 4	− 2	+ 2	+ 7	+ 1	− 4	—

Hence, only those days were entered as foggy or misty when fog or mist was recorded for each of the twenty-four hours of the day. The hourly temperature and pressure of such days were extracted from the daily sheets, and the averages for each month calculated. Those days were regarded as clear days when the sun shone at least several hours, and when fog or mist was virtually absent. Means were similarly calculated for these clear days. Thereafter the monthly means for the three years were ascertained, and the hourly results 'bloxamed' as explained above.

The results show two sets of curves, essentially different the one from the other, the monthly curves for foggy and misty days revealing a diurnal variation of pressure quite distinct from that of the curves for clear days. Table V. shows the differences between the two sets of curves, the *plus* sign (+) indicating a higher pressure for foggy days, and the *minus* sign (−) a lower pressure for those days as compared with the pressure for clear days at the same hours. With clear skies the daily maximum pressure occurs at 11 A.M. in winter, but at 2.30 P.M. in summer; whereas with fog or mist it occurs at all seasons between 10 and 11 P.M. With clear skies the minimum occurs at 4.30 A.M., but with fog at 6 A.M.

From Table V. it is seen that, with fog, pressure is higher than with clear skies from 7 P.M. to 4 A.M., attaining the absolute maximum at midnight, but lower from 5 A.M. to 6 P.M., the absolute minimum being about noon. The important bearing of these results on solar and terrestrial radiation and other physical inquiries is obvious. No small part of the large excess of pressure during the night hours in fog is probably occasioned by the latent heat set free in the condensation of the aqueous vapour into fog or mist. This necessarily, in the circumstances, increases the barometric readings where it occurs, viz., on the top of the mountain, and particularly at night when the surface temperature of the mountain

is low. Owing to the high winds which often prevail at the time, and the formation of the fog being chiefly confined to the restricted area of the mountain top, the increased pressure is not relieved by the formation of an ascending current, and hence pressure is increased at the top, being the restricted area where the condensation takes place.

TABLE V.—*Showing Difference of Pressure, in Thousandths of an Inch, at the Ben Nevis Observatory,* 4,406 *feet, between foggy days and clear days respectively. The* plus *sign shows pressure on foggy days the greater; the* minus *sign, less.*

Hour	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1 A.M.	+17	+18	+14	+15	+14	+19	+17	+17	+17	+24	+23	+23	+18
2 "	+15	+13	+ 8	+ 8	+ 7	+11	+11	+13	+11	+16	+16	+20	+12
3 "	+11	+ 7	+ 4	+ 3	+ 4	+ 7	+ 8	+ 8	+ 6	+12	+13	+16	+ 8
4 "	+ 7	+ 3	+ 2	+ 0	+ 1	+ 1	+ 4	+ 3	+ 2	+8	+10	+11	+ 4
5 "	+ 5	+ 0	+ 0	− 4	− 2	− 3	− 1	− 1	+ 0	+ 5	+ 9	+ 8	+ 1
6 "	− 4	− 9	− 6	− 7	− 7	− 7	− 3	− 3	− 4	+ 1	+ 5	+ 2	− 4
7 "	− 8	−10	− 6	− 8	− 8	− 9	− 6	− 7	− 7	− 2	− 0	− 2	− 6
8 "	− 9	− 9	− 6	− 8	− 8	−10	− 8	−10	−11	− 7	− 5	− 7	− 8
9 "	−15	−14	− 9	−10	−10	−13	−10	−13	−14	−12	− 9	−12	−12
10 "	−15	−14	− 9	−10	−10	−13	−11	−14	−15	−16	−15	−15	−14
11 "	−14	−13	− 9	−11	−10	−13	−11	−13	−15	−19	−19	−18	−15
Noon	−11	−11	− 9	−12	−12	−15	−11	−12	−15	−22	−22	−18	−14
1 P.M.	−12	−13	−11	−11	− 9	−11	−10	−11	−15	−23	−21	−18	−14
2 "	−11	−12	− 9	− 9	− 8	−10	−10	−10	−11	−20	−19	−18	−12
3 "	− 9	−10	− 5	− 5	− 5	−10	− 8	−10	−11	−17	−16	−15	−10
4 "	− 6	− 7	− 5	− 4	− 2	− 4	− 4	− 6	− 5	−13	−13	−13	− 7
5 "	− 4	− 4	− 3	− 3	− 1	− 2	− 4	− 4	− 2	− 9	−11	−12	− 5
6 "	− 3	− 1	− 2	+ 0	+ 3	+ 3	− 1	− 1	− 1	− 5	− 9	−10	− 2
7 "	+ 1	+ 3	+ 1	+ 4	+ 7	+10	+ 5	+ 4	+ 4	+ 0	− 2	− 4	+ 3
8 "	+ 5	+ 7	+ 5	+ 7	+ 8	+11	+ 8	+ 8	+ 8	+ 5	+ 3	+ 2	+ 6
9 "	+ 8	+11	+ 7	+ 9	+ 9	+13	+11	+12	+14	+16	+11	+ 9	+11
10 "	+11	+14	+ 9	+12	+12	+17	+15	+18	+19	+22	+16	+15	+15
11 "	+15	+18	+12	+15	+16	+21	+20	+22	+24	+28	+23	+21	+20
Midnight	+21	+24	+16	+19	+19	+27	+24	+25	+25	+29	+26	+27	+24

The work of recopying on daily sheets the hourly observations of both observatories, which show at a glance the relations of the two sets of observations to each other, is in progress, and already about half of the three years is finished. These sheets show the relative times of occurrence at the top and bottom of the mountain respectively of changes of pressure, temperature, humidity, and the other subjects of observation, together with their relative amounts. As the work proceeds the entries on the sheets are compared with the bi-diurnal weather maps of the weekly weather report of the Meteorological Office, and copious notes are made of the relations of the observations of the two observatories to the cyclones and anticyclones of north-western Europe at the time. One example may be here referred to. It frequently happens that the temperature difference of the two observatories, which is generally about 16°·0, becomes less and less during the time of the anticyclone, and occasionally temperature is higher at the top than at the foot of the mountain. But as the anticyclone gives way, and the cyclone advances, temperatures assume their normal difference. Now the observations show two marked types of weather in these circumstances: one type when the difference is brought about by a falling temperature at the top while temperature at Fort William remains practically stationary; and the other type when temperature rises at Fort William while at the top of Ben Nevis it is stationary. These different types at the present stage of the inquiry seem to point to important well-marked characteristics of the approaching weather.

Earth Tremors.—Report of the Committee, consisting of Mr. G. J. SYMONS, Mr. C. DAVISON (*Secretary*), Sir F. J BRAMWELL, Professor G. H. DARWIN, Professor J. A. EWING, Dr. ISAAC ROBERTS, Mr. THOMAS GRAY, Sir JOHN EVANS, Professors J. PRESTWICH, E. HULL, G. A. LEBOUR, R. MELDOLA, *and* J. W. JUDD, Mr. M. WALTON BROWN, Mr. J. GLAISHER, Prof. C. G. KNOTT, Prof. J. H. POYNTING, *and* Mr. HORACE DARWIN. (*Drawn up by the Secretary*).

APPENDIX—*Account of Observations made with the Horizontal Pendulum. By* Dr. E. VON REBEUR-PASCHWITZ, p. 309.

THE Committee were appointed to consider the advisability and desirability of establishing in other parts of the country observations upon the prevalence of earth-tremors, similar to those now being made in Durham in connection with coal-mine explosions.

In the present report descriptions are given of several instruments which have been used in the study of earth-tilts and earth-pulsations. The list is not a complete one, some having already been included in the reports of the Committee on the Lunar Disturbance of Gravity for 1881 and 1882, drawn up by Messrs. G. H. and H. Darwin.[1] The first of these valuable reports also contains an account of the pendulum with double-suspension mirror, used in the well-known experiments in the Cavendish Laboratory, Cambridge. The extraordinary sensitiveness of this pendulum led Mr. Horace Darwin to design another form of the instrument, smaller and simpler in construction, but capable of measuring smaller angles than are required in these experiments. The method of determining the angular value of the scale-divisions has also been altered. The new pendulum was made some months ago by the Cambridge Scientific Instrument Company, and Mr. Darwin, being unable at the time to give much attention to it, has lent it to the Committee for trial. The preliminary experiments have been made by the Secretary at Birmingham, chiefly under Mr. Darwin's guidance, and the results are described below. The Committee think it most desirable that the observations should be continued in Birmingham, and also made in other parts of the country.

One of the most delicate instruments that have been used for the observation of earth-tilts is the horizontal pendulum of Dr. E. von Rebeur-Paschwitz, who has described the results obtained with it in several valuable memoirs. The Committee considered that an account of these observations in English would be of great use, and at their request Dr. von Rebeur-Paschwitz kindly consented to write the very interesting and valuable summary which forms an appendix to this report.

Nadirane of M. C. Wolf.—The nadirane erected in 1863 by M. d'Abbadie at Abbadia, near Hendaye, is described in the reports for 1881 and 1882,[2] as well as some of the results which have been obtained with it.

[1] *Brit. Assoc. Reports*, 1881, pp. 93–126; 1882, pp. 95–119. In referring to these reports in the following pages they will be quoted as the Reports for 1881 and 1882.

[2] *Brit. Assoc. Reports*, 1881, pp. 116–118; 1882, pp. 102, 103. The following is a list of M. d'Abbadie's papers on this subject:—

The nadirane now to be described was designed by M. Wolf for use at the Paris Observatory.[1] It differs from that of M. d'Abbadie in two important particulars: (1) The beam of light is made to traverse a horizontal, instead of a vertical, layer of air, thereby avoiding the effects of variations in temperature. (2) The relative fixity of the object-glass and the observing microscope is rendered immaterial by employing differential, instead of absolute, measures of the position of the image.

The bath of mercury rests on the limestone floor of the observatory cellar, which, being at a depth of 27 metres, is free from surface vibrations, and remains at a practically constant temperature. Above the bath, and rigidly connected with it, is a hollow prism of cast iron, the hypotenuse face of which carries a plane mirror of silvered glass inclined to the horizon at an angle of 45°. The mercury-bath is closed by a horizontal object-glass, 24 cm. in diameter, about 30 m. in focal length, and cut so as to give the least aberration to yellow light. The closing of the bath was found to be necessary in order to prevent the action of the mercury vapour on the silvering of the mirror. A second plane mirror of silvered glass, and 14 cm. in diameter, is fixed to the horizontal surface of a support rigidly connected with the framework of the mercury bath. On the floor of the cellar and in a line at right angles to the vertical face of the hollow prism is a metal plate, through a hole in which a beam of monochromatic yellow light passes. This beam is reflected by the inclined mirror, and again by the horizontal mirror and mercury, and is then returned as a double beam by the inclined mirror to near its origin, where the two images are observed with a microscope of small magnifying power.

If the luminous point is rigidly connected with the optical centre of the object-glass of the microscope the two images, M. Wolf shows, are only displaced with respect to one another when the reflecting apparatus is rotated about a horizontal axis. The luminous point and microscope might indeed be held by the hand. The parts of the reflecting apparatus must, however, be invariably fixed with respect to one another and their support; and, the temperature of the cellar being constant, it follows that the only error can arise from rusting of the metallic parts.

1. 'Appareil destiné à reconnaître les Mouvements du Sol par la Variation de la Pesanteur relativement aux Masses Solides du Terrain,' Paris, Acad. Sci., *Compt. Rend.*, vol. xxxiv. 1852, pp. 942, 943.

2. 'Direction de la Pesanteur,' Paris, Acad. Sci., *Compt. Rend.*, vol. lxi. 1865, p. 838.

3. 'Etudes sur la Verticale,' Assoc. Franç., *Compt. Rend.*, vol. i. 1872, pp. 159–168.

4. 'Observations relatives à une Communication de M. Plantamour sur le Déplacement de la Bulle des Niveaux à Bulle d'Air,' Paris, Acad. Sci., *Compt. Rend.*, vol. lxxxvi. 1878, pp. 1528–1530.

5. 'Sur les Variations de la Verticale,' Paris, Acad. Sci., *Compt. Rend.*, vol. lxxxix. 1879, pp. 1016, 1017.

6. 'Recherches sur la Verticale,' Bruxelles, Soc. Scien., *Annales*, 5e année, 1881, pp. 37–51.

7. 'Sur les Petits Tremblements de Terre,' Paris, Acad. Sci., *Compt. Rend.*, vol xcviii. 1884, pp. 322, 323.

8. 'La Fluctuation des Latitudes Terrestres,' *Bull. Astron.*, mars 1892. An abridged translation of this paper is given in *Nature*, vol. xlvi. 1892, pp. 65, 66.

[1] 'Sur un Appareil propre à l'Etude des Mouvements du Sol,' Paris, Acad. Sci., *Compt. Rend.*, vol. xcvii. 1883, pp. 229–234. Notes on several changes in the construction of this apparatus are given in the *Rapports Annuels sur l'Etat de l'Observatoire de Paris*, 1881, pp. 20, 21; 1883, p. 14; 1884, pp. 20, 21; 1885, pp. 13, 14.

With this apparatus it is possible to measure an angle of $0''\cdot05$; with M. d'Abbadie's nadirane, one of $0''\cdot03$.

M. Wolf informs me that the only result of his observations, which have been carried on for several years, is that there has been no permanent change of level in the floor of the observatory cellar.

Tromometer of P. T. Bertelli.—This instrument being now well known a brief account will be sufficient here. In its original form it consists of a mass of 3 kilogrammes suspended by a copper wire 1 mm. in diameter and 3 m. long. In the 'normal tromometer,' which is the form generally adopted throughout Italy, a mass of 100 grammes is suspended by a very fine copper-wire $1\frac{1}{2}$ m. in length from a stout arm projecting from the column which forms the stand of the instrument. From the centre of the bob of the pendulum there projects downwards a short style, the point of which, after reflexion in the hypotenuse-face of a right-angled prism, is observed with a microscope. In some instruments the style ends in a small disc, on which are ruled two fine lines at right angles to one another. The mirror is provided with a glass micrometer-scale ruled to tenths of a millimetre, and tenths of a division may be estimated by the eye. It is therefore possible with this instrument to measure an earth-tilt of about $1\frac{1}{3}''$. The scale can also be rotated so as to determine the direction of the movement.

Tremor-recorder of Professor J. Milne.—The pendulum consists of a weight of 7 lb. suspended by a fine iron wire 3 feet $3\frac{1}{4}$ inches long. The upper end of this wire is soldered into a small hole in a plate which forms the top of a tripod-stand about 5 feet high. From the base of the bob a spike projects downwards, and is kept by a spring in contact with the end of a long light vertical pointer made of a strip of bamboo. The length of the pointer is about $16\frac{1}{2}$ inches, the short arm, which is in contact with the spike of the pendulum, being about $\frac{1}{70}$th of the length of the longer arm. The instrument is made recording by discharging a spark every five minutes from the end of the pointer, and thus perforating a band of paper which is moved by clockwork beneath the end of the pointer. A second band of paper moves at right angles to the former, in order to avoid the loss of a record in case the pointer should move parallel to the first band. Though designed independently, this instrument, as Professor Milne remarks, is similar to one previously made by M. Bouquet de la Grye.[1]

To avoid the friction arising from the movement of the pointer, M. Chesneau suggests that the bob of the pendulum should be a lens, a point of light close to it forming an image at a greater distance, which should record on a strip of photographic paper the movements of the pendulum.[2]

The tromometer now used by Professor Milne is described in the 'Report of the British Association' for 1892 as well as in the two last papers in the following list, in which he has given the results of his work on this subject:—

1. 'Earth Tremors,' 'Japan Seism. Soc. Trans.,' vol. vii. pt. 1, 1883, pp. 1–15.
2. 'Earth Pulsations,' 'Nature,' vol. xxviii. 1883, pp. 367–372.
3. 'Earth Tremors,' 'Nature,' vol. xxix. 1884, pp. 456–459.

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[1] Paris, Acad. Sci., *Compt. Rend.*, vol. xcvi. 1883, p. 1857; also *Rapport Annuel sur l'Etat de l'Observatoire de Paris pour l'Année* 1885 (Paris, 1886), pp. 24–26.

[2] M. B. de Chancourtois, 'Sur un Moyen de constater par Enregistrement continu les petits Mouvements de l'Écorce Terrestre,' Paris, Acad. Sci., *Compt. Rend.*, vol. xcvi. 1883, pp. 1857–1859.

4. 'On the Observation of Earth-tips and Earth Tremors,' 'Nature,' vol. xxxii. 1885, pp. 259–262.
5. 'Earth Tremors in Central Japan,' 'Japan Seism. Soc. Trans.,' vol. xi. 1887, pp. 1–78.
6. 'Earth Tremors in Central Japan,' 'Japan Seism. Soc. Trans.,' vol. xiii. pt. 1, 1888, pp. 7–19.
7. 'Earth Tremors and the Wind,' 'Roy. Met. Soc. Journ.,' vol. xiv. 1888, pp. 64–72.
8. 'Earth Pulsations in relation to certain Natural Phenomena and Physical Investigations,' 'Japan Seism. Journ.,' vol. i. 1893, pp. 87–112.
9. 'On Earth Pulsations and Mine Gas,' 'Fed. Inst. Mining Eng. Trans.,' vol. v. 1893, pp. 203–219.
10. 'Reports on the Seismological Phenomena of Japan,' 'Brit. Assoc. Rep.,' 1881, p. 202; 1883, pp. 211, 212; 1884, pp. 249–251; 1885, pp. 374–378; 1887, pp. 219–226; 1888, pp. 433–435; 1892, pp. 107–113.

Seismic Oscillations of the Ground-water Surface.—Some interesting observations have recently been made on this subject by Professor Franklin H. King in wells in the Wisconsin agricultural experiment station farm.[1] The instrument employed consists of a copper float connected with the end of the short arm of a lever. The longer arm is three times as long as the other, and at the end carries a pen which traces the magnified fluctuations of the water-level on a moving sheet of paper. The recording apparatus is placed on a slab over the top of the well.

The well in which these observations were made is 40 feet deep, and is tubed with 6-inch iron pipe down to the rock (sandstone), 37 feet below the surface, the water having a mean depth of about 20 feet. At a distance of 140 feet from the well there is a railway line.

When the records from this well were examined, numerous sharp, short period curves were found, which were at first supposed to be due to accidental disturbances of the apparatus. But the fact that they were always dependent from the main curve, indicating a rise of water in the well, led to their closer examination and to their association with the movement of trains past the well. 'The strongest rises in the level of the water are produced by the heavily-loaded trains which move rather slowly. A single engine has never been observed to leave a record, and the rapidly moving passenger trains produce only a slight movement, or none at all, which is recorded by the instrument.' The curve is produced by 'a rapid but gradual rise of the water, which is followed by only a slightly less rapid fall again to the normal level, there being nothing oscillatory in character indicated by any of the tracings nor observable to the eye when watching the pen while in motion. The downward movement of the pen usually begins when the engine has passed the well by four or five lengths, and when the pen is watched it may be seen to start and to descend quite gradually, occupying some seconds in the descent.'

The cause of these movements of the ground-water surface is not quite clear. Possibly the earth, being depressed by the weight of the train, and sinking into the ground-water, may displace it laterally, and thus cause it to rise under the surrounding area; or the compression of the zone of capillarily saturated soil lying just above the ground-water surface, or its frequent recoils from the shock imparted by the moving train, may force some of the capillary water out of the soil, and thus raise the mean level of the ground-water.

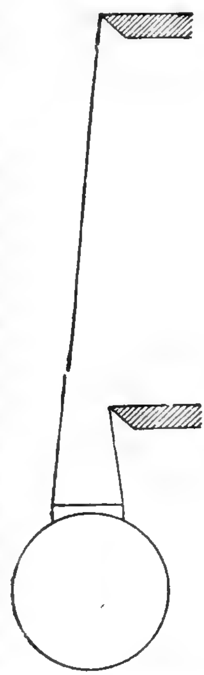
[1] 'Observations and Experiments on the Fluctuations in the Level and Rate of Movement of Ground-water, &c.' United States Weather Bureau, Bull. No. 5, pp. 67–69. See also a paper by Mr. Isaac Roberts, F.R.S., in the *Brit. Assoc. Rep.*, 1883, p. 405.

Bifilar Pendulum designed by Mr. Horace Darwin.

The pendulum used by Messrs. G. H. and H. Darwin in their experiments at Cambridge is fully described in the Report for 1881 (pp. 93–112). The principle of this instrument was suggested to them by Lord Kelvin, and may be briefly described as follows. A heavy weight is suspended by two converging brass wires, which only allow the cylinder to move in a direction at right angles to the plane they are in. A fine silk fibre is attached at one end to the bottom of the weight and at the other to a fixed support, and passes through two thin wire loops on the edge of a small circular mirror. The ends of the silk fibre are brought close together, so that the two parts are inclined at a considerable angle. Thus, a very small displacement of the pendulum at right angles to the plane of the mirror will cause it, and a ray of light reflected by it, to turn through considerable angles.

Mr. Horace Darwin has designed the new bifilar pendulum on the same principle (fig. 1). The mirror is circular and $\frac{1}{2}$ inch in diameter, and itself forms the bob of the pendulum. Two hooks about $\frac{1}{4}$ inch apart are fixed to its upper rim and are hooked on a very fine silver wire which supports the mirror. The points to which the ends of this wire are fixed are some distance apart in a vertical direction, one being very nearly vertically above the other, and are attached to supports in the frame of the instrument.

FIG. 1.



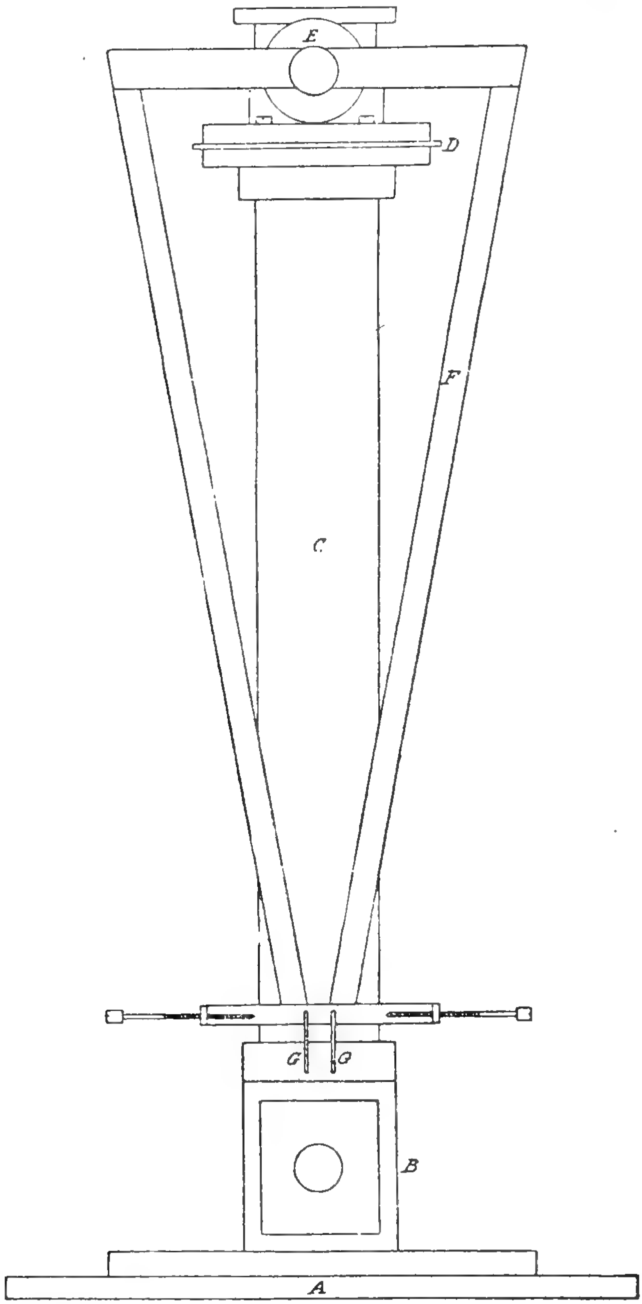
Any simple tilt of the ground may be resolved into component rotations about a vertical line and two horizontal lines, one perpendicular, and the other parallel, to the face of the mirror. The first rotation produces no appreciable effect, the second changes the horizontal distance between the two points of support, thus rendering the instrument more or less sensitive, according as the distance is diminished or increased. By the third rotation, the upper support is moved through a greater distance than the lower, causing a deflection of the mirror about a vertical axis. If, for instance, the mirror be suspended in a north and south plane, facing a gas-jet at some distance to the west of it, and if the north part of the suspending wire be the longer, it is obvious that the pendulum will only indicate those tilts which take place in an east and west direction, or the east and west component of tilts which take place in other directions; and that a tilt towards the west will cause the reflected beam to deviate towards the south.

The pendulum is at present placed in this position. The mirror faces west, and it will be convenient in this description to refer to the sides as north or south, &c. The front or west view of the instrument is given in fig. 2, on one-third the real scale. The base, A, is carried by three levelling-screws, 6 inches apart, and is made in two pieces fixed together;[1] but it would be better for the future to have it cast in one, together with the brass box, B, 2 inches broad, $2\frac{7}{8}$ inches high, and

[1] In order to equalise the temperature in the instrument, thick metal of good conductivity has been used throughout in the construction. Brass and gun-metal have been used, although copper would have been considerably better.

$1\frac{5}{8}$ inch from front to back. One of the screw-feet is placed due east of the axis of the pendulum, and the line joining the other two is therefore north and south. The lower half of the front contains a circular window,

FIG. 2.



$\frac{3}{4}$ inch in diameter, through which the pendulum-mirror is visible. This box is only a little larger than the mirror, and is connected above with a brass tube, C, $1\frac{5}{8}$ inch in external diameter and $12\frac{3}{8}$ inches high,

ending in a brass cap $2\frac{1}{4}$ inches high, so that the total height of the instrument above the top of the foundation is only $19\frac{7}{8}$ inches.

A section of the instrument by an east and west plane is given in

FIG. 3.

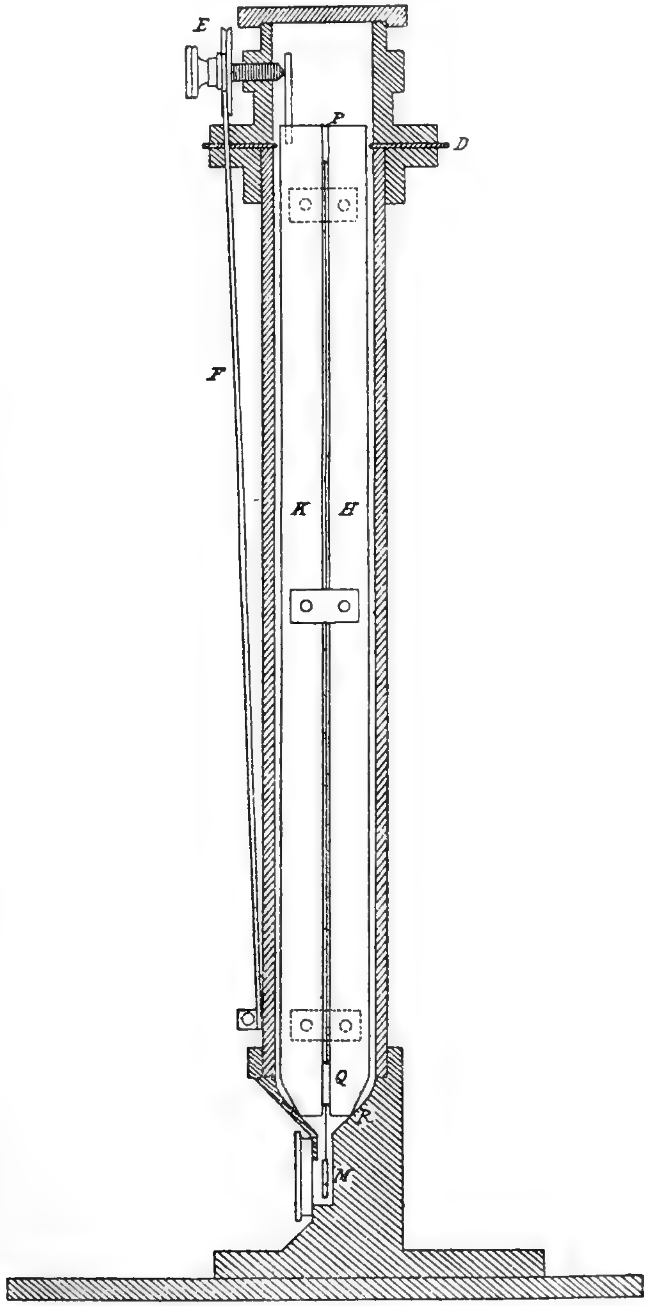


fig. 3,[1] and shows the manner in which the pendulum-mirror, M, is suspended. Two $\frac{1}{2}$-inch square brass bars, H and K, are firmly screwed together (H being on the east side), and carry between them two pulley

[1] In figs. 2 and 3 the same letters denote the same parts of the instrument.

wheels, P and Q, with V-shaped grooves, which turn stiffly on their axles. This part of the instrument will be referred to as the 'frame.' The thin silver wire which supports the mirror passes partly round each of these wheels, and is fastened by a small screw in their edges. The wire hangs down in a loop just below the frame, and is stretched tight when the mirror is hooked on. The north portion of the wire is attached to the upper wheel, and the south portion to the lower. A convenient vertical adjustment is given to the mirror by turning the pulleys and winding some of the silver wire on to them; the friction with which they turn prevents them running back.

When the mirror is suspended in this manner the frame and mirror are inserted into the brass tube, the lower end of the frame resting on the hollow conical surface, R, of the passage from the tube to the mirror-box, so that the mirror hangs within the latter. A rectangular opening in a circular brass plate, D (fig. 2), at the top of the tube admits the frame and allows it to move without rotation in an east and west direction. A thin rod, which passes through a hole in the south-east side near the top of the cap of the tube, is kept pressing by a spiral spring against the bar H (fig. 3), and this holds the frame against the north side of the rectangular opening, and also against the end of the screw, E (figs. 2 and 3), on the west side. Thus, all movement of the frame inside the tube is prevented, except that in an east and west direction, produced by turning the screw, E. Another and much stronger spring outside the cylinder keeps the screw E pressed in one direction in order to prevent any backlash in the screw.

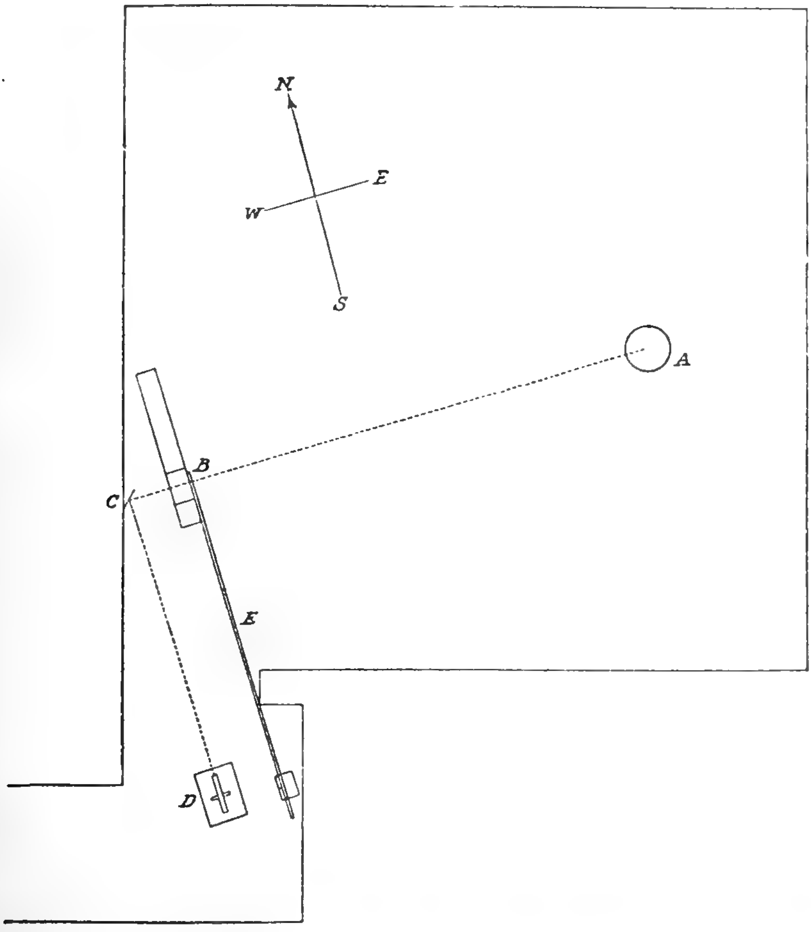
Before the plate, D, and the cap are screwed on, the mirror-box and tube are filled with paraffin oil, so that the pendulum and supports are entirely immersed in it. The effect of this is to make the pendulum absolutely dead-beat and capable of registering slow earth-tilts only. It is therefore unaffected by the rapid tremors such as would be produced by the rattling of passing vehicles.

The two west or front levelling-screws being equidistant from the east and west line through the centre of the instrument, it is evident that the inclination of the pendulum along the latter line is not changed if one of the screws be raised and the other depressed by equal amounts. The sensitiveness of the pendulum can be increased or decreased by turning the screws in this manner. At present this is done by hand, but it might be desirable to put a slow motion for their adjustment which could be worked from a distance. The inclination of the pendulum in the east and west direction can be altered by the east or back levelling-screw (called the 'back-leg' in the Report of 1881) without affecting the sensitiveness, and a movement of the same kind but of far greater delicacy can be given to the frame by the screw, E. This can be done by hand, or a small turn of the screw can be made by the lever, F.

The distances between the levelling-screws being known, and also the number of threads to the inch, it is evident that the tilt given to the instrument by one turn, or fraction of a turn, of the back-leg could be estimated. In the present form of the instrument the tilt is, however, given to the frame by turning the screw, E, through a known angle. If a be the distance between the bottom of the frame and the point at which the screw acts, b the breadth of the frame, and α the semi-vertical angle of the hollow cone, R, on which the frame rests, a movement of the screw, E, through a distance, h, will tilt the frame through an

angle whose circular measure is $2h/(2a-b \tan \alpha)$. In the present case $a=14{\cdot}36$ inches, $b={\cdot}56$ inch, $\alpha=44°$, and the number of threads on the screw is 100 to the inch. One complete turn of the screw will therefore tilt the frame through an angle of 146·4 seconds. A fractional turn of the screw may be made by the lever, F, which can be clamped to it by a screw in front. The lever ends below in a rectangular plate with ends projecting outwards; and, by two screws working through these ends, and abutting against the stops, G, the range of the lever's movement can be regulated. The length of the lever is 335·5 mm., so that

FIG. 4.



with the range of movement of 14·4 mm. of the bottom of the lever the tilt given to the frame is exactly one second.

It will be useful to give the general arrangement of the instrument now in use in Birmingham. It is erected in a cellar, the plan of which is shown in fig. 4. The pendulum is placed at A on a foundation described below. The line A B runs east and west. Ten feet west of the pendulum a board, B, is placed on the floor of the cellar. This board, which was used in the experiments at Cambridge, contains a pair of rails on which a carriage with three legs slides, bearing a gas-jet. On the east side of the carriage is a screen, pierced by a circular hole, one inch in diameter, having on the west side a piece of ground glass, and

on the east side a fine wire. The image of this wire formed by reflexion, first, in the pendulum-mirror, and then in a plane mirror, at C,[1] is observed with a telescope, D, furnished with cross-wires and placed in the passage just outside the cellar. A wooden bar, E, is attached at one end to the side of the carriage, and at the other end is graduated to tenths of an inch, the index-pointer being near the floor to the right of the telescope. The carriage is also provided with a screw-motion, which can be worked from the telescope-seat, but it was found unnecessary to use this, as the image can be rapidly and accurately adjusted on the vertical cross-wire of the telescope by gently tapping the end of the graduated bar.

When the instrument is in order, nearly all operations can be carried on in the passage without entering the cellar. Strings attached to the two sides of the lever are guided by hooks and brought round to either side of the telescope, so that the angular value of the scale-divisions can be determined without leaving the telescope. The gas-jet also can be lighted from the same place. The only occasion for entering the cellar is to readjust the pendulum when one end of the scale-divisions, which occupy a length of about 9 inches on the graduated bar, approaches the index-pointer. But this can be rapidly done by a slight turn of the screw used for tilting the frame. In a few minutes the image becomes steady, and if this be done about the time of day when the tilt is changing in direction, the movement in so short a time will be so small that it may be safely neglected.

The house in which the pendulum is installed lies on the west margin of Birmingham. The rock is Bunter sandstone, but this is covered at the surface by a thick bed of clayey sand, with occasional layers of rounded pebbles. The nearest edge of the road in front of the house is 11 yards from the pendulum. A single-line suburban railway runs in a deep cutting at the bottom of the garden, about 80 yards from the pendulum. But no disturbance has ever been noticed from either passing carts or trains, the short vibrations or tremors produced by them being too rapid to affect the pendulum, and the local bendings of the ground caused by their weight apparently having no effect.

The Foundation of the Pendulum.[2]—A circular hole, 3 feet in diameter, was made to a depth of $8\frac{1}{2}$ feet. The bottom of the hole is covered with a layer of concrete, C (fig. 5), 2 ft. 2 in. in thickness, and on the surface of this is placed vertically a cast-iron water-pipe, A, 6 ft. 6 in. long, $10\frac{1}{8}$ inches in external diameter, and $\frac{9}{16}$ inch thick, and weighing about 3 cwt.; so that the pipe projects about 2 inches above the cellar floor. A further layer of concrete, nearly 2 feet in thickness, surrounds the bottom of the pipe and keeps it in position, and the pipe itself is also filled with concrete to within 2 feet of the top. The pendulum stands on an iron plate, B, which rests at three points only on top of the pipe; lateral displacement is prevented by pieces projecting a little way down the inside of the iron pipe. In order to isolate the stand from the cellar floor, the iron pipe is surrounded by earth only to about 2 feet from the top, and then an earthenware drain-pipe, D, is placed surrounding the pipe, leaving an air-space between. The interval between the drain-pipe and the sides of the hole is filled with earth, and the brick pave-

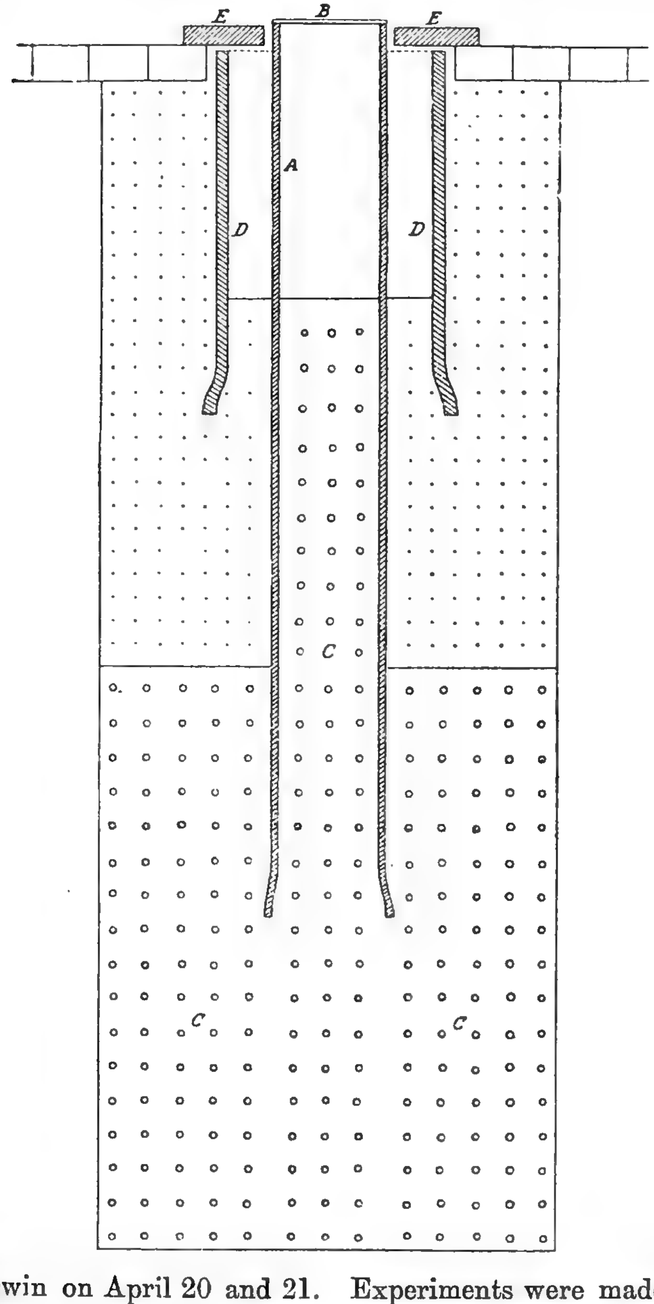
[1] This mirror is an ordinary plate-glass looking-glass. It should, however, be made of worked glass, as should also the window of the mirror-box (B, fig. 2).

[2] This foundation was designed by Mr. Horace Darwin.

ment of the cellar is taken up for a few inches round the drain-pipe. A wooden plate, E, covers the drain-pipe without touching it, and rests only on the cellar floor.

Angular Value of Scale-divisions.—The pendulum was erected by Mr.

FIG. 5.



Horace Darwin on April 20 and 21. Experiments were made to determine the angular value of the scale-divisions at various times between May 1 and 25, and again between August 1 and 3. The first trials were unsatisfactory, the image seldom returning to the same or nearly the same position. Some of the causes of failure were easily remedied; but

even in the latest attempts there is still some slight discrepancy between the positions of the image after successive to-and-fro movements of the lever.[1]

If the bottom of the lever be moved to the left, it is evident that the screw advances and that the frame is tilted to the east. When this is done the movement of the image is at first rapid, but in two or three minutes becomes nearly insensible, and after five minutes no displacement of the image can be perceived. In all the later and more satisfactory trials the lever was moved every ten minutes, and in the intervals the gas was turned down. It should be added that in the evenings when these experiments were made the pendulum always indicates a movement to the west.

The range of motion of the bottom of the lever was regulated so as to give a tilt of two seconds to the frame, and the corresponding lengths of the scale in inches, as determined on May 24, were as follows:—

+7·02	−6·65	+7·20	−6·95	+6·66	−6·96
+6·90	−6·85	+6·83	−6·97	+6·94	−6·65

A plus sign indicates a tilt to the west, and a minus sign a tilt to the east. Thus the average of six tilts of two seconds to the west gives 6·92±·05 inches as the corresponding scale-value, and the average of six similar tilts to the east gives 6·84±·04 inches. The difference between these two values may no doubt be in part attributed to the westerly tilting of the instrument. If, however, the mean of the scale-values of successive pairs of tilts be taken, the effect of this westerly tilting will be eliminated, if it may be supposed to be uniform throughout the twenty minutes allowed for the to-and-fro movements of the lever and for the subsequent readings. The average of these six means is 6·88±·03 inches. This value is probably the most accurate of the series, and a tilt of one second will therefore be taken to correspond to 3·44 inches of the scale.

The distance of the gas-jet from the pendulum being 10 feet, the angle through which the mirror turns for an east or west tilt of one second is therefore $\frac{1}{2}\tan^{-1}\frac{3\cdot44}{120}$, or 49 minutes.

Since the two parts of the silver wire which support the mirror always lie in the vertical plane through their points of support, the angle through which the mirror turns for a given east or west tilt is independent of the distance between the mirror-hooks; it depends only on the horizontal and vertical distances between the two points of support of the silver wire. If c be this horizontal distance, and θ the angle through which the mirror turns for an east or west tilt of one second, it is evident that $c\theta$ is constant. If x be the decrease in the value of c, due to a given southerly tilt of the frame, and δ the corresponding increase in the value of θ, then $\delta = x\theta/c$. Hence, if the frame be tilted through one second in a north and south line, the change in the value of θ is θ^2, and the corresponding change in the scale-value above given is therefore $\frac{1}{70}$th of that value. It follows that, in order to make the error small, θ should be small; that is, the scale should be a long way from the pendulum. The original instrument used in the Cavendish Laboratory experiments was free from this error. It would be possible to replace one of the fine

[1] It is hoped that this discrepancy will disappear with another arrangement of the lever which Mr. Darwin has designed.

wires supporting one side of the mirror by two converging wires, and thus to allow it to move only in an east and west direction, and so eliminate this error. It would, however, have the drawback of complicating the instrument.

If d be the vertical distance between the points of support of the silver wire, it is obvious that the circular measure of one second is $c\theta/d$, and therefore $c=d/2940$. In the present instrument d is about 12 inches, so that the horizontal distance between the points of support is only 0·004 inch.

On the first three days of August, the scale-value for a tilt of two seconds was redetermined in the manner described above. The average scale-values of six pairs of east and west tilts on each evening were

$$6{\cdot}39\pm{\cdot}03,\ 6{\cdot}06\pm{\cdot}06, \text{ and } 6{\cdot}14\pm{\cdot}08 \text{ inches},$$

and the average of the eighteen pairs was $6{\cdot}20\pm{\cdot}04$ inches. Between the end of May and the beginning of August, the scale-value for one second changed from 3·44 to 3·10 inches, and there must, therefore, have been a tilt towards the north of about seven seconds.

Sensitiveness of the Pendulum.—Except on two occasions, which will be referred to below, the image has always been perfectly steady, and chiefly to this is due the extreme delicacy of the pendulum. If the gas-jet be displaced by $\frac{2}{100}$ths of an inch, the image and the vertical cross-wire in the telescope are clearly separated, and a displacement of $\frac{1}{100}$th of an inch of the gas-jet can be easily detected. Thus the scale-value of one second being 3·44 inches, it follows that we can observe a tilt of the ground of less than $\frac{1}{300}$th of a second;[1] and since the pendulum might be rendered more sensitive, and the optical arrangements improved, it would not be impossible to detect a tilt of $\frac{1}{1000}$th of a second, or even less than this if desired.

Observations with the Pendulum.—The principal objects of the experiments being to test the working of the instrument, observations were made when convenient, and not at regular intervals. They were made frequently enough, however, to give some idea of the nature of the daily motion. At first the movement indicated appeared to be always to the west, and the observations, though not generally continued later than 10 P.M., showed no trace of a return movement to the east. This westerly tilting, of at first about a second a day, appeared to be chiefly due to the settling of the foundation, and by the end of June became nearly imperceptible. Towards the end of May and the beginning of June, observations on the daily movement were made for about two weeks consecutively. The direction of the movement changed from east to west at from 7 to 9 A.M., and from west to east at from 10 to 12 P.M., but these epochs were altered when the continued westerly tilting ceased. During the middle of August, the easterly movement lasted till noon or about 2 or 3 P.M. Subsequent experiments, described below, seem to show that this daily movement may be, in part at least, due to the action of convection currents in the oil surrounding the mirror.

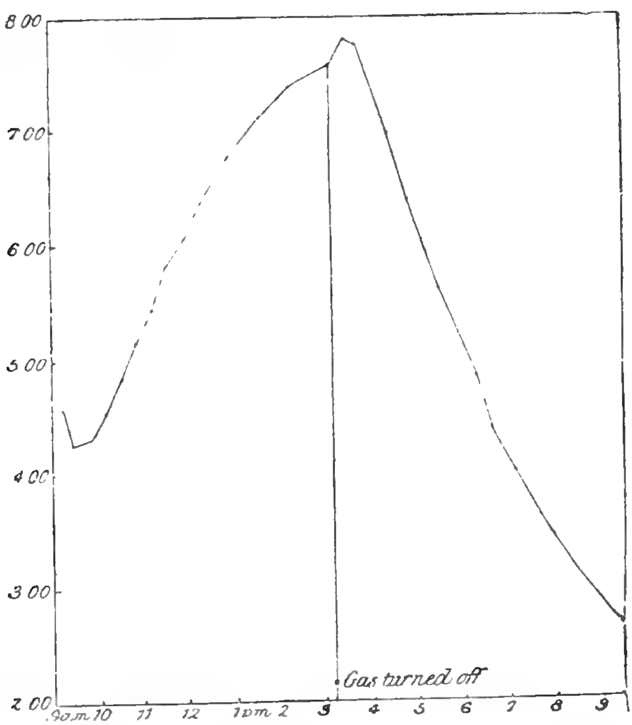
The pendulum in the Cavendish Laboratory having been extremely sensitive to slight changes of pressure on the floor of the room, it seemed desirable to make some similar experiments with the present instrument. I stood for one minute about a foot and a half west of the pendulum, and,

[1] An isosceles triangle with a base one inch long and each of the equal sides 1,000 miles would have a vertical angle of about $\frac{1}{300}$th of a second.

returning quickly to the telescope, found there had been an apparent tilting of about one-sixth of a second to the east. Standing for the same time on the east side of the pendulum, there was an apparent tilting to the west. At a distance from the pendulum these effects were much less marked. After sitting for a short time at the telescope-seat in the passage outside the cellar a somewhat similar, but very slight, effect is noticeable. For about a minute the image remains perfectly steady. It then starts slowly, but rather suddenly, to the right, indicating a movement to the east, the total deflection in eight minutes being about $\frac{1}{30}$th of a second. I attributed these movements at first to my weight bending the cellar floor, but some experiments made afterwards at Mr. Darwin's suggestion showed that they were due rather to changes of temperature, and that the deflections caused by my weight were in reality almost imperceptible.

Supposing the foundation to remain fixed, the effects of a change in

FIG. 6.



the distribution of temperature might be manifested in two ways—either by the unequal expansion of different parts of the instrument or by convection currents in the paraffin oil. Since the gas-jet stands west of the pendulum, the expansion due to its heat would produce an apparent tilting to the east. On the other hand, since the vertical axis about which the mirror turns lies to the south of its centre (see fig. 1) the effect of convection currents on the oil would be to cause an apparent tilting to the west. Thus the initial deflection of the mirror in the preceding experiments appears to be due to expansion.

If, however, the heating be continued for some time a retrograde movement sets in. On August 20 the gas was kept alight for six hours,

from 9.12 A.M. to 3.12 P.M.; it was then turned down, and readings were continued for six hours longer. The results are illustrated by the curve in fig. 6. The effect of expansion is shown by the movement to the east for a short time after the gas is lighted, and that of contraction by an increase in the rate of westerly deflection immediately after the gas is turned down. The most important movement is that of more than a second to the west while the gas was up, and to the east when it was turned down. There can be little doubt that it is due to the action of convection currents in the paraffin oil, in which the mirror and frame are immersed.

An attempt was next made to determine the part of the instrument whose expansion produced the first deflection. For this purpose a card-board box, 12 inches long, $5\frac{1}{4}$ inches broad, and 4 inches deep, was filled with hay. It was first placed so as to shield the upper part of the instrument, leaving the mirror-box and levelling-screws uncovered, with the result of preventing the first easterly movement. The gas was kept alight for two hours (11.30 A.M. to 1.30 P.M.); it was then turned low down, and readings were taken at intervals during the next three hours. After one minute the image was seen to the left of the vertical cross-wire, indicating a deflection to the west; and this westerly movement continued at a very nearly uniform rate during the whole time the gas was alight, and also for about half an hour afterwards. Its velocity then rapidly diminished, and after a quarter of an hour an easterly movement set in, whose velocity soon became uniform and equal to that of the westerly movement. The total westerly deflection of the mirror in the first $2\frac{1}{2}$ hours was equivalent to a tilt of $1\frac{1}{2}$ seconds.

The box was then placed resting with its longer side on the wooden cover of the drain-pipe. Strings were tied to each end and brought round by hooks to the telescope-seat, so that the box could be moved backwards and forwards in front of the mirror-box and levelling-screws. These were shielded by the box from the gas-jet, which was kept alight for two hours (12.40 to 2.40 P.M.). In order to take the readings, the box was drawn to one side for a few seconds and then replaced. Readings were also continued for several hours after the gas was turned down. The resulting curve is similar to that in fig. 6. It follows, therefore, that the first easterly movement which takes place after the gas is lighted is caused by the expansion of the brass-tube more than by that of the levelling-screws.

It is evident from these experiments that the natural movements of the pendulum in its present form and position may be seriously affected by the slight changes of temperature which take place in ordinary cellars. To guard against these, Mr. H. Darwin proposes to alter the mode of suspension of the mirror. The two hooks by which it hangs on the silver wire will be placed in a line at right angles to the plane of the mirror. The instrument will also be protected by a case, and perhaps by immersion in water. For photographic registration, it would be better to use a glow electric lamp, or, better still, an induction-coil spark, instead of a continuously burning gas-jet.

A few experiments were made on the bending of the cellar-floor by means of a heavy weight, but without much success. This was due partly to the tilting so caused being nearly or quite masked in the daily movement of the mirror, partly because to move the weight I was obliged to enter the cellar, and frequently approach close to the instrument. The

heavy mass employed is about 84 lb., and consists of a part of the cast-iron pipe of which the foundation is made. When it was placed at successive distances of a foot, from 2 to 9 feet, nearly west of the pendulum, the tilting of the column was inappreciable; and this was also the case when it was placed alternately at distances of 2 and 9 feet. If, however, it was put alternately nearly west and east of the pendulum, and close to the wooden cover of the drain-pipe, the tilting, though very slight, was perceptible, and apparently in the direction away from the heavy mass. For the reasons above stated, however, the results were not altogether concordant, so that these experiments prove little more than the nearly complete isolation of the stand.

Earth Pulsations of June 3 *and* 6, 1893.—At 5.43 P.M. on June 3 the image was, as usual, perfectly still, and was adjusted to the cross-wire without difficulty. At 6.29, when I went to take the next reading, it was marching slowly and steadily from side to side of the field of view. At first I timed each separate oscillation, and found their period to be nearly regular, and between 15 and 17 seconds in length. At this time the range of movement was greatest, but it was impossible to determine its amount exactly, owing to the shifting of the mean position of the image produced by the heat of the gas-jet. The movement continued to be considerable for about five minutes, then it gradually diminished, and by 6.37 was decidedly less, perhaps half that at 6.30. Between 6h. 35m. 15s. and 6h. 37m. 40s. the image crossed the wire fourteen times, the average period of the seven complete oscillations being therefore 20·7 seconds. At 6.42 the image had become steady again. I then tried to measure the range of the movement when it was greatest from my recollection of the average limiting positions of the image, and found the scale-value to be 0·44 inch, and the corresponding angular value about $\frac{1}{8}$th of a second.

At 6.46 the oscillations began again, and continued from this time until 8.13, with a few short intervals, when they either ceased or were almost imperceptible; but throughout this time the range was always very small, never, I believe, exceeding $\frac{1}{30}$th of a second. The oscillations were also more constant in range and in their mean position, so that the range could be determined by making the image in each limiting position coincide with the cross-wire. Between 6h. 48m. 40s. and 6h. 53m. 40s. there were sixteen complete oscillations, giving an average period for each of 18·8 seconds. At 6.56 the range was about $\frac{1}{60}$th of a second, and at 7.8 about $\frac{1}{80}$th of a second. After this the oscillations became smaller, and it could just be seen that the image was in motion. This continued until just before 7.19, when the movement became greater again and more regular. Between 7h. 19m. 0s. and 7h. 25m. 43s. there were twenty complete oscillations, the average period being 20·2 seconds; and the range immediately after the latter time was about $\frac{1}{60}$th of a second. Then the oscillations again decreased, and at 7.36 the image was nearly steady, occasionally being just visible on one side or other of the cross-wire. Between 7h. 42m. 58s. and 7h. 45m. 50s. there were five complete oscillations, but the movement was so slight that one or two of them may have been missed. At 7·54 I left the cellar, returning about ten minutes later. About 8.8 the last series of oscillations began. Between 8h. 8m. 15s. and 8h. 11m. 20s. ten complete oscillations were counted, the average period being 18·5 seconds, and the range immediately afterwards was found to be about $\frac{1}{120}$th of a second. After 8.13, though I watched almost con-

tinuously for two hours and a half, no further oscillations were perceptible, and the usual steady movement was resumed.

Another series of pulsations was observed on June 6 at 7.21 A.M., and lasting nearly an hour, but I was unable at this time to watch them carefully. From 7.0 to 7.8 the image was perfectly steady. At 7.21, when I went down to the cellar again, and for about ten minutes afterwards, it was performing oscillations even more extensive than on the previous occasion, but it was again not possible to measure the exact range owing to the variable limiting positions. Between 7h. 32m. 25s. and 7h. 35m. 22s. there were nine complete oscillations, the average length being 19·7 seconds. At the end of this interval the range had decidedly diminished. At 7.45, from my recollection of the limiting positions of the image, I found the maximum range to be about $\frac{1}{6}$ second; and I do not think this estimate can be much in error. By 7.55 the range had diminished to about $\frac{1}{15}$ second (measured). At 8.7 the movement was almost imperceptible, and ten minutes later the image was steady again.

It is probable that these earth-pulsations were the dying-out vibrations from some distant and severe earthquakes, but I have not been able to identify them with any particular shocks. On May 23 a violent earthquake was felt at Thebes, in Greece, laying a great part of the city in ruins, and it is stated that shocks were felt daily for some time afterwards. Some of these may possibly have produced the earth-pulsations observed on June 3 and 6.

Horizontal Pendulum of Dr. E. von Rebeur-Paschwitz.

Dr. von Rebeur-Paschwitz's horizontal pendulum is a modified form of Professor Zöllner's, which is described in the Report for 1881, pp. 112–114. The principal difference consists in the method of suspension of the pendulum, the two stretched springs of Professor Zöllner's instrument being replaced by steel points working in agate cups, which allow a nearly frictionless motion. In the following pages the pendulum used by Dr. von Rebeur-Paschwitz is first described, and this is followed by an account of the improvements suggested to him by the experience of several years' work with the instrument.[1]

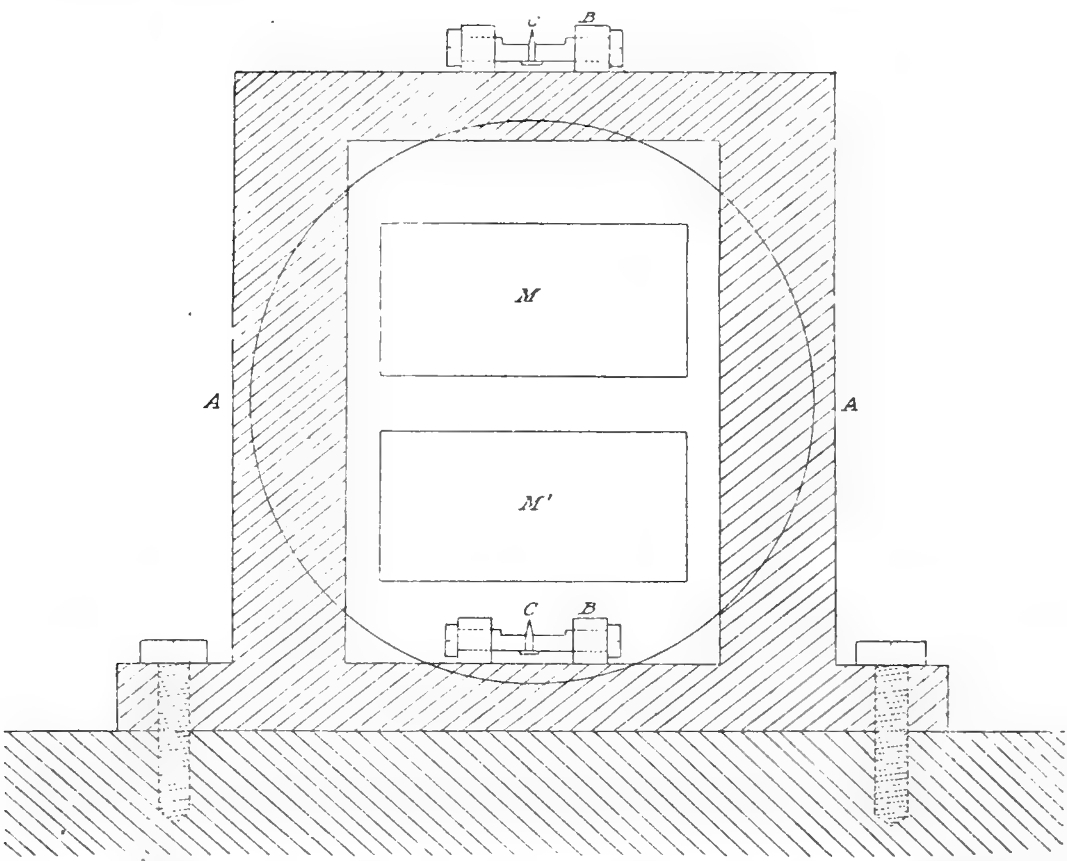
The heavy cast-iron tripod-stand of the pendulum consists of a low cylindrical vessel, on which, at equal distances apart, are three projections for the reception of the foot-screws, the whole being cast in one piece. The cylinder is open at the top, and, after the instrument is adjusted, is covered with a closely-fitting bell-glass. The screws have a pitch of 0·36 mm., and are provided with large heads, so that a very small change may be given by them to the level of the stand. The distance between each pair of screws is 435 mm. Exactly half-way between two of the foot-screws and opposite the third is an opening in the cylinder, which is closed by a plano-concave lens, 75 mm. in diameter, and about 4·6 m. in focal length, the optical axis of the lens being horizontal and directed towards the centre of the tripod-stand.[2]

[1] The pendulum is described in Dr. E. von Rebeur-Paschwitz's valuable memoir, *Das Horizontalpendel*, &c., pp. 17–41. The suggested improvements are contained in pp. 213–216 of the same memoir, and also in letters to members of this Committee.

[2] The lens is used for photographic registration; for direct vision it is replaced by a plane glass.

The support of the pendulum (fig. 7) is arranged symmetrically with respect to the diameter of the tripod-stand, which passes through the third foot-screw. It consists of a strong rectangular frame, A, the plane of which is parallel to the lens above mentioned (whose position is shown by the circle in the figure), and is screwed to the base of the tripod-stand behind the lens. It carries two horizontal cylinders, B, B, one lying vertically over the other, which can be turned round their axes with considerable friction. In the middle of the cylinders are very fine steel points, C, C (shown projecting upwards in the figure). These are screwed to the cylinders, so that they are perpendicular to their axes, and project only a little way from their surfaces. The vertical distance between the axes of the cylinders is 68 mm.

FIG. 7.



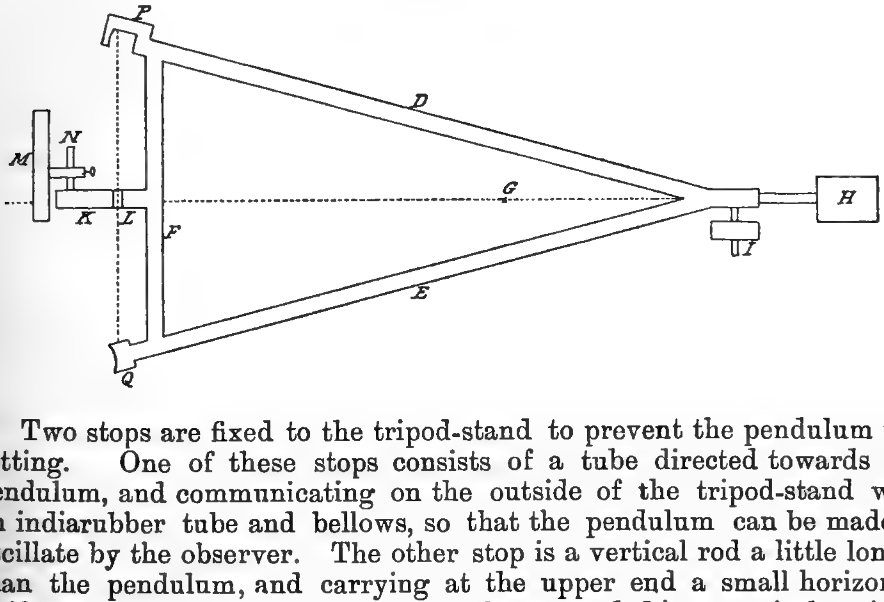
The pendulum is made completely of brass in the form of an isosceles triangle (fig. 8). D, E, F are thin tubes; H, a small weight attached at the vertex of the triangle. At P and Q are two small spherical agate cups, 2·5 mm. in radius, their centres being 68 mm. apart. The steel points against which the cups rest also project from the axes of the cylinders by 2·5 mm., so that in every position the points are perpendicular to the tangent-planes to the cups. The rod, K, which projects perpendicularly from the tube, F, has a perforation, L, in the direction P Q for the reception of a knife-edge, on which the pendulum can be suspended in a vertical position. M is a mirror which projects through the

frame of the support, and can be rotated about the axis of a rod, N, parallel to P Q. The weight of the whole pendulum is 42 grammes, and the distance of the centre of gravity, G, from the axis of rotation is 100 mm.

Immediately beneath the mirror, M, and in the same plane with it, a fixed mirror, M′ (fig. 7), is attached to the tripod-stand, and can be rotated about a horizontal and vertical axis from outside the instrument.

To adjust the pendulum the mirror, M, is fixed on the rod, N, so that its surface is approximately perpendicular to the axis of the triangle. The centre of gravity, G, of the whole pendulum is next brought into that axis by supporting the pendulum at two points of the axis, near L and H, and by displacing the small weight, I. The cylinders, B, B, are then rotated until the steel points are directed towards the agate cups, and are parallel respectively to the lines G P and Q G. This can be done with sufficient accuracy by the eye by applying a cardboard triangle of the form G P Q. When the pendulum is suspended the arrangement is therefore such that the pressure is directed perpendicularly to the cups, and there is consequently no tendency to slip.

FIG. 8.



Two stops are fixed to the tripod-stand to prevent the pendulum upsetting. One of these stops consists of a tube directed towards the pendulum, and communicating on the outside of the tripod-stand with an indiarubber tube and bellows, so that the pendulum can be made to oscillate by the observer. The other stop is a vertical rod a little longer than the pendulum, and carrying at the upper end a small horizontal knife-edge. On this the pendulum can be suspended in a vertical position by means of the perforation at L, and the knife-edge then agrees nearly with the direction of the true axis of rotation. By finding the period of oscillation in this position the constant required for the reduction of the observations when the axis is in an inclined position can be determined with all desirable accuracy.

The apparatus for photographic registration is placed about $4\frac{1}{2}$ metres north of the pendulum. The source of light is a petroleum lamp capable of burning fourteen hours, and enclosed in an opaque case. In this there is a movable vertical slit, 20 mm. in length, through which the light passes to the lens[1] of the pendulum apparatus. The lamp-case

[1] In the more recent experiments at Strassburg, the plane mirror, M, attached to the pendulum is replaced by a concave mirror, and this renders the use of the lens superfluous.

is mounted on a small iron stand, whose position can be adjusted both vertically and horizontally, and the stand is cemented to a pillar.

By the side of the lamp is placed the recording apparatus. The photographic paper is wrapped round a horizontal roller, 20 cm. long and $56\frac{1}{2}$ cm. in circumference, which is turned round with considerable friction on its axis once in fifty hours, the paper being held fast to the roller by two bars. Parallel to the roller, and at the same height as its axis, is a cylindrical lens, 20 cm. long and 5 cm. in focal length. After reflexion at the pendulum-mirror, M, and a double passage through the lens in front of it, the pencil of light sent out from the slit is focussed by the cylindrical lens to a fine point on the surface of the photographic paper. An image is also formed by reflexion from the fixed mirror, M′, and, by rotation of that mirror, can be brought into any desired position. This fixed point of light records a straight line on the photographic paper, and is also used for marking the time, the light being shut off for five minutes at the beginning of each hour by a small screen moved by the clockwork. The recording apparatus is mounted on a heavy cast-iron plate, through which pass the cords of the weight and the pendulum of the driving-clock. It is covered by a wooden box, closed at the top by a lid, and having in front a horizontal slit for the passage of the light. The lamp is changed twice a day; and, two being used, a fresh one can be inserted in the case by a slide without appreciable loss of time. Thus, when once well adjusted, the working of the instrument requires very little attention.

Suggested Alterations.—The sensitiveness of a given horizontal pendulum increases with its period of oscillation, and this is greater the smaller the inclination of the axis to the vertical.[1] The difficulty of obtaining and preserving very fine steel points therefore imposes a limit to the sensitiveness of the instrument. In order to preserve the form of the points, it is desirable that the pendulum should be as light as possible. It should therefore be made of aluminium, whose specific gravity is about $\frac{3}{10}$ths that of brass. This would at the same time reduce still further the little friction that exists. The distance between the steel points might also be increased with advantage to double its present value, or even to 20 cm., without altering the distance of the centre of gravity from the axis of rotation.

The two lateral foot-screws should be removed and their places taken by screws for adjusting the position of the lower of the two steel points. The third foot-screw, which regulates the sensitiveness of the pendulum, should also be replaced by a screw for adjusting the position of the upper steel point. In the original instrument, if the parts of the foot-screws projecting downwards are of unequal lengths, a temperature-correction must be introduced; but with the removal of the foot-screws this may be rendered unnecessary.

The head of the screw which regulates the position of the upper steel point should be provided with divisions and an index, so that the axis of rotation may be tilted through a known angle. The period of oscillation (T_0) of the pendulum in a horizontal position of the axis may then be determined indirectly as follows. If T_1 and T_2 be the periods of

[1] If T_0 be the period of oscillation when the axis is horizontal, T that when the axis is inclined at an angle, i, to the vertical, $T^2 = T_0^2 \operatorname{cosec} i$.

oscillation when the axis is inclined at angles i_1 and i_2 to the vertical, we have the following equations:—

$$\tan \tfrac{1}{2}(i_2+i_1)=\tan \tfrac{1}{2}(i_2-i_1)\frac{T_1^{\,2}+T_2^{\,2}}{T_1^{\,2}-T_2^{\,2}},$$

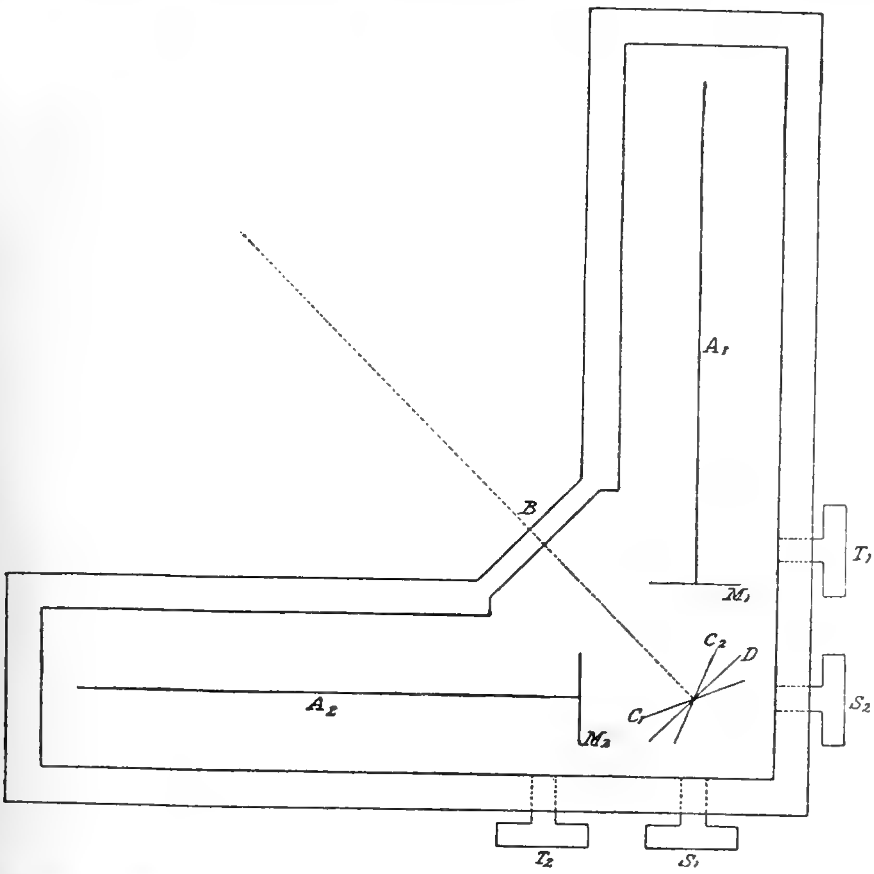
and

$$T_0=T_1\sqrt{\sin i_1}=T_2\sqrt{\sin i_2}.$$

Thus, T_1, T_2, and i_2-i_1 being known, we can find i_1, i_2, and consequently T_0.

When the point of light leaves the photographic paper, the pendulum has to be readjusted by turning the foot-screws. This always

FIG. 9.



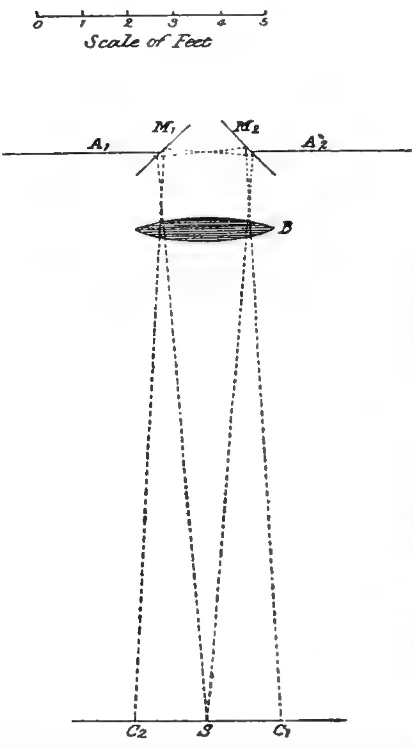
produces a certain change of stress, which it is desirable to avoid, especially as in some places the movement is so great that such corrections are necessary every few days. By the employment of a 'correcting-mirror,' which can be turned by screws, the point of light can be brought back to the middle of the roller by the observer without touching or approaching the instrument. The arrangement will be evident from fig. 9.

It would be a great advantage if the length of the roller used for the photographic records were increased, and an arrangement devised for displacing the roller in the direction of its axis, so that the same paper could be used during two consecutive rotations. The rapidity of rota-

tion of the roller might also be increased, so as to give a more detailed representation of the recorded movements.

Combination of two Pendulums in Perpendicular Planes.—The method of arranging two pendulums in perpendicular planes is shown in fig. 9. A_1 and A_2 are the pendulums in the planes of the meridian and prime vertical respectively, M_1 and M_2 their mirrors. The light enters in the direction of the dotted line through a lens of about 4 m. focal length at B, and returns after reflection along the same course. C_1 and C_2 are the correcting-mirrors of the two pendulums, D a fixed mirror at right angles to the path of the light. All three mirrors can be rotated from outside the apparatus about a vertical and horizontal axis. S_1 and S_2 are screws for the longitudinal correction of the lower steel points of the two pendulums, T_1 and T_2 screws for the lateral correction of the upper steel points. The lamp and roller are, as before, placed side by side. When the apparatus is properly adjusted no corrections are necessary, except those required for the rotation of the correcting-mirrors, in order to keep the points of light on the middle of the roller.

FIG. 10.



Combination of two Pendulums in the same Plane.—As already remarked, the length of the period of oscillation and consequently the sensitiveness of the pendulum are limited by the difficulty of obtaining very fine steel points. By arranging two exactly similar pendulums in one plane, as shown in fig. 10, we can obtain four times the exactitude of registration without increasing the sensitiveness of the pendulums. A_1 and A_2 are the pendulums, M_1 and M_2 their mirrors inclined at angles of 45° to the common axis of the pendulums and at right angles to one another. The light passes through the slit, S, and after double reflection by the mirrors, and refraction by the lens, B, forms two images at C_1 and C_2. If there be any change of level or of the vertical in a direction inclined to the common axis of the pendulums, both are equally deflected towards the same side of the axis. The angle between the mirrors alters by double this deflection, and the distance between the images C_1 and C_2 is four times as great as would be produced by the employment of a single pendulum and fixed mirror. This greater accuracy of registration would be of great advantage in investigations on small movements such as are produced by the influence of the moon.

List of Memoirs by Dr. E. von Rebeur-Paschwitz.—The following is a list of memoirs published by Dr. von Rebeur-Paschwitz on the horizontal pendulum, and the results so far obtained with it:—

1. ‘Ueber das Zöllner'sche Horizontalpendel und neue Versuche mit demselben,’ ‘Verh. des naturw. Ver. zu Karlsruhe,’ Bd. x., 1887.
2. ‘Ueber einen Versuch, die Veränderungen der Horizontalebene mit Hülfe

eines Zöllner'schen Horizontalpendels photographisch zu registriren.' 'Astr. Nach.,' Bd. 118, 1887, col. 9–16.
3. 'Ueber die Anwendung des Horizontalpendels zur Untersuchung der Bewegung des Erdbodens.' 'Astr. Nach.,' Bd. 120, 1888, col. 273–278.
4. 'The Earthquake of Tokio, April 18, 1889,' 'Nature,' vol. xl. 1889, pp. 294–295.
5. 'Resultate aus Beobachtungen am Horizontalpendel zur Untersuchung der relativen Variationen der Lothlinie,' 'Astr. Nach.,' Bd. 126, 1890, col. 1–18.
6. 'Wellenbewegung des Erdbodens in Puerto Orotava,' 'Naturwissenschaftliche Wochenschrift' (Berlin), Bd. vi. 1891, pp. 123–124.
7. 'Ueber Horizontalpendel-Beobachtungen in Wilhelmshaven, Potsdam und Puerto Orotava auf Teneriffa,' 'Astr. Nach.,' Bd. 130, 1892, col. 193–216.
8. 'Das Horizontalpendel und seine Anwendung zur Beobachtung der absoluten und relativen Richtungs-Aenderungen der Lothlinie,' 'Nova Acta der ksl. Leop. Carol. Deutschen Akademie der Naturforscher,' Bd. lx. 1892, pp. 1–216.
9. 'Neue Beobachtung mit dem Horizontalpendel, nebst Untersuchungen über die scheinbare tägliche Oscillation der Lothlinie,' 'Astr. Nach.,' Bd. 132, 1892, col. 33–58.
10. 'Beobachtung kleiner Erderschütterungen am selbstregistrirenden Horizontalpendel auf den Sternwarten zu Strassburg und Nicolaiew,' 'Astr. Nach.,' Bd. 132, 1892, col. 113–118.
11. 'Berichtigung zu dem Aufsatz : neue Beobachtungen mit dem Horizontalpendel,' 'Astr. Nach.,' Bd. 132, 1893, col. 143–144.
12. 'Ueber die Möglichkeit, die Existenz von Mondgliedern in der scheinbaren täglichen Oscillation der Lothlinie nachzuweisen,' 'Astr. Nach.,' Bd. 133, 1893, col. 1–23.
13. 'Ueber eine muthmassliche Fernwirkung des japanischen Erdbebens von Kumamato, 28 Juli 1889,' 'Astr. Nach.,' Bd. 133, 1893, col. 97–100.
14. 'Ueber eine merkwürdige Fehlerquelle astronomischer Beobachtung,' 'Astr. Nach.,' Bd. 133, 1893, col. 137–144.
15. 'Ueber die Aufzeichnung der Fernewirkungen von Erdbeben,' 'Petermann's Geographische Mittheilungen,' 1893, Heft 9, pp. 201–212.

APPENDIX.

Account of Observations made with the Horizontal Pendulum.
By DR. E. VON REBEUR-PASCHWITZ.

In reply to the invitation of the Committee to furnish an account of the results obtained by myself with the horizontal pendulum, I have the pleasure of submitting the following outlines.

In 1887, during some preliminary experiments with a rather roughly constructed instrument at Karlsruhe, I noticed that the motions of a horizontal pendulum placed in the E. W. plane in one of the cellars of the Technische Hochschule were sufficiently regular to permit the application of continuous photographic registration. With few exceptions, the pendulum, though entirely at liberty to swing, when observed through a telescope from a distance of $4\frac{1}{2}$ m. always appeared to be at rest. When this was not the case, the oscillations performed were generally very small, and so regular that it was easy to observe the elongations, and thus obtain a very accurate value of the mean position of the pendulum. The vibrations of the ground caused by traffic, which were sometimes very noticeable owing to the situation of the cellar next to one of the greatest thoroughfares of the town, never appeared to have any other effect than

to produce a slight vertical swing of the mirror attached to the end of the pendulum. The position of equilibrium received no alteration whatever. After having placed the pendulum in the plane of the meridian, a successful attempt was made to photograph its movements, the instrumental arrangement being very similar to that which is generally employed in registering the variations of the magnetic elements.

During the above observations, which only extended over a short interval of time, a daily oscillation was the most important part of the motions of the pendulum. I therefore employed the name of 'zero-point' for the mean position of the day, not expecting that at other places the irregular movements of the zero-point would far exceed those due to the daily period. The application of the word 'zero-point' may thus not appear very appropriate. I have, however, retained it during all the further investigations in order to avoid confusion, and because the character of the changes of the zero-point would not be better represented if one were to speak of 'irregular' or 'secular' changes.

In 1888 a grant from the Prussian Academy of Sciences allowed me to undertake observations on a more extended scale. Two horizontal pendulums, which have been in use up to the present time, were carefully constructed by Messrs. Repsold, of Hamburg, whilst the necessary photographic apparatus was furnished by Mr. Wanschaff, of Berlin. In 1891 both instruments received small alterations, reference to which will be made later on.

Observations at Potsdam and Wilhelmshaven.—In November 1888 a column was erected in a circular cellar situated below the east tower of the Astrophysical Observatory at Potsdam. One of the pendulums was placed in it with its plane in the meridian, and was at first observed by the aid of a telescope from a distance of 4·7 m. Different degrees of sensitiveness were given to the instrument in order to study the regularity of the motions. It was found during these trials that the period of oscillation of the pendulum is very dependent on the magnitude of the amplitude, even when the latter is quite within the limits which in an ordinary pendulum ensure the isochronism of the oscillations. Later experiments at Strassburg, which Professor Becker was kind enough to make for me by using a chronograph, showed that the formula

$$T=T_0+C\,.\,\alpha,$$

in which C is a constant, represents the observed values of T in a satisfactory way. The correction $C\alpha$ is rather large when the period of oscillation is great, and has to be taken account of if one wishes to obtain an accurate value of T_0, which is the constant required for reducing the observations. As it is impossible to make good observations of T when α is very small, α ought always to be observed at the same time in order to be able to compute C and T_0.

Further experiments were made to try the effect of weights deposited in the neighbourhood of the column. Its foundation was about 90 cm. below the floor of the cellar, and a ditch was left free round it. Notwithstanding these precautions, a considerable tilting of the column of about $0''\cdot7$ was caused, when a weight of 100 kilogrammes was moved from one side of the ditch to the other. This tilting did not take place suddenly, but required a considerable time, just as the soil did to recover its former state after the pressure had been removed.

When a person walked *slowly* round the space contained between the

double circular wall of the cellar, which is a circle of about 6 m. diameter, the corresponding motion of the pendulum was still distinctly visible. This effect of pressure formed a simple means of setting the pendulum swinging, when it was necessary to determine the period of oscillation.

It follows from these observations that the neighbourhood of the column carrying a horizontal pendulum ought to be guarded against receiving any additional weights during the course of observations.

On the other hand, it was observed that the turning of the dome which covers the east tower of the observatory had no disturbing influence on the horizontal position of the pendulum, though the vibrations of the soil could be distinctly felt by the observer.

An experiment was also made to mitigate certain effects of microseismic movements. In the first days of February 1889 a strong gale was blowing, and the pendulum was found to be in a very disturbed state. When trying to photograph the curve a broad and very irregular band was obtained, which showed that the pendulum was not only constantly swinging, but that it was subject to certain small changes of the vertical. A point was fixed to the free end of the pendulum pointing downward into a dish containing a mixture of water and glycerine. Although the point only just touched the liquid, the pendulum was now unable to swing, but the slow motions of its plane of equilibrium took place as before. Photographs were taken for about a fortnight, and a very remarkable case of earth pulsations, to which I will refer later, was observed during this period. But, unfortunately, I was obliged to abolish the glycerine, because it was evident that the position of the pendulum was influenced by certain molecular effects.

After these preliminary experiments, observations were taken between April 1 and June 6, and again from June 18 until the end of September 1889. The column and pendulum were protected by a strong wooden box nailed with tinfoil, which also covered the ditch and only contained a small window, through which the light passed, and through which it was possible to get at the foot-screws of the pendulum. The photographic apparatus and lamp stood in a passage connecting the cellar with another one lying to the north of the former, and were separated by a door, which was also nailed with tinfoil and had two slits for the light to pass. This door was only opened when it became necessary to bring the light point back to the middle of the drum. On such occasions a thermometer hanging near the column was read, and the same was done in the adjoining passage every other day when the paper was changed. During the summer the temperature of the passage in which the lamp was burning constantly was generally 1° or 2° C. higher than that of the cellar. The door connecting the passage with the cellar to the north of it was only opened twice every day, when the lamps or the paper had to be changed.

At Wilhelmshaven the horizontal pendulum stood in a cellar of the Imperial Naval Observatory, whilst the rest of the apparatus was placed in an adjoining cellar lying to the south of the first. Openings were made in the wall to let the light pass. All arrangements were very similar to those described for Potsdam. Professor Boergen, the director of the observatory, and his former assistant, Dr. Eschenhagen, very kindly undertook to do all the work connected with the observations, and these were carried on from March 7 until October 5. Amongst the several difficulties which at first presented themselves, and caused several interruptions of the observations, the most serious arose from the excessive

moisture of the air in these cellars. The slightest difference of temperature was sufficient to produce dew on the glasses, and for a long time during the months of May and June, when the temperature of the air was rising quickly, observations became quite impossible.

Observations at Puerto Orotava, Teneriffe.—The third station where I was able to try the horizontal pendulum was at Puerto Orotava, on the island of Teneriffe. The Spanish houses in this country do not have any underground cellars, but through the kindness of an English lady, Mrs. C. Smith, the widow of a well-known resident of the Canary Islands, a small chemical laboratory on her grounds, which had been empty for many years, was placed at my disposal. The estate bears the name 'Sitio del Pardo,' and is well known to all English visitors of the place, many of whom may have noticed the little laboratory, because it is covered with a most beautiful specimen of a white creeping rose. The Sitio occupies the eastern flanks of an old lava stream, which runs from the Montañeta de la Horca to the north towards the sea, and forms a platform above the Puerto on which a large hotel is now built.

The nature of the volcanic soil did not allow a similar foundation for the instrument as was offered by the cellars at Potsdam and Wilhelmshaven. Instead of making a hole into the ground I preferred to erect it on the cemented floor of the little laboratory, which is on the same level with the outer grounds, with the exception of the east side, where the ground is higher.

The little building, the direction of which very nearly agrees with the magnetic meridian, is divided into two rooms, of which the one to the south was used to place the horizontal pendulum, whilst the one to the north was reserved for the photographic apparatus. A door leading from the former into the garden was closed by masonry work, and another one connecting the two rooms received only the necessary openings for the light to pass. Thus the pendulum was guarded as much as possible against all disturbances. Observations were begun on December 26, 1890, and continued without any interruption until April 27. Much trouble arose from the bad quality of the petroleum. The lamps, which had burned fourteen hours and more at the first two stations, had to be constantly watched, and many hours of observation were lost. This, however, was of no importance for the final reduction of the observations, because the extreme regularity of the motions of the pendulum at this station always permitted the gaps to be filled up by interpolation.

The following paper, 'Das Horizontalpendel und seine Anwendung zur Beobachtung der absoluten und relativen Richtungsänderungen der Lothlinie,'[1] contains all the readings taken from the photographic curves by the aid of a glass scale.

Results.

A preliminary study of the first two sets of observations shows that the investigation might be divided as follows: I. The influence of the moon; II. The daily oscillation and its changes; III. The motion of the zero-point; IV. Seismological phenomena and others of a more incidental character.

I. *The Influence of the Moon.*—Since Professor G. H. Darwin and his brother, Mr. Horace Darwin, made their well-known experiments at the

[1] *Nova Acta der kais. Leop. Carol. Acad.* lx. Nr. 1.

Cavendish Laboratory at Cambridge, no observer is likely to expect much from a *short* series of observations, however complete it may be, for the demonstration of gravitational or tidal effects of the moon. Holding this view, I was much surprised to find, when first inspecting the photographs, that in the curves obtained at Wilhelmshaven a lunar wave was distinctly visible, which produced a decided change in the general aspect of the curves in different phases of the moon. This led me to make a careful reduction, with the object of finding a lunar wave in all the three sets of observations. The final results of this investigation I have lately published in No. 3169 of the 'Astronomische Nachrichten.' But as it required a good deal of calculation before the conclusions there given were arrived at, it may be useful to say a few words about the way in which the influence of the moon has been determined.

We owe to Professor Darwin the evaluation of the principal effects the moon may produce on the solid earth, apart from the well-known deflections of the plumb-line due to the tidal forces of the moon. All these different indirect and direct lunar influences form a complex phenomenon, the general forms of which have to be ascertained before one may try to analyse it. The first object of our investigation, therefore, is to find whether the observations require the assumption of a lunar wave, what is its form and its position referred to the meridian passage of the moon, and how the size of the wave varies with the declination of the moon.

The problem is apparently identical with the problem of the ocean tides, if, instead of the heights of the water, the ordinates of the curves are introduced. The same method might therefore be employed which was indicated by Professor Darwin and Professor Boergen for the reduction of the ocean tides. But there is this difference between tidal observations and observations of the plumb-line, that in the former the *principal* changes in the height of the water are due to the attraction of the sun and moon, the mean level remaining very nearly constant, whilst in the latter the changes due to solar and lunar influence are *extremely small* compared with the periodical changes which arise from thermal effects and the very marked variations of the mean daily position of the plumb-line. Thus the principal difficulty in reducing a set of observations with the object of determining the lunar influence is to eliminate as much as possible the zero-point and the daily period.

The following is a very simple method for eliminating the zero-point, which I constantly employed in determining the mean daily oscillation of a group of days. It gives very satisfactory results provided that care be taken to exclude such days on which the motion of the zero-point is too irregular to admit the assumption of a simple mathematical formula.

If $f_0, f_1, \ldots f_{23}$ is a series of twenty-four equidistant values, which in the present case would represent the means of a number of single readings of the curves, it is always possible, when the readings form an uninterrupted series, to add to those twenty-four values the following six: f_{-3}, f_{-2}, f_{-1}, $\ldots f_{24}$, f_{25}, f_{26}, the meaning of which is clear from the suffixes given. These thirty values may be represented with sufficient accuracy by the following formula:—

$$f_p = \alpha + 2\beta\left(p - \frac{23}{2}\right) + 4\gamma\left(p - \frac{23}{2}\right)^2 + P_p,$$

in which the first part contains the changes due to the variation of the zero-point and P all periodical changes. The period being twenty-four hours, we have

$$P_p = P_{24+p}.$$

Thus, if we form the differences $\Delta_1 = f_{21} - f_{-3}$, $\Delta_2 = f_{22} - f_{-2}$, . . . $\Delta_6 = f_{26} - f_2$ we get six equations, from which we obtain by the method of least squares

$$\beta = \frac{1}{288}\left\{\Delta_1 + \Delta_2 + \Delta_3 + \Delta_4 + \Delta_5 + \Delta_6\right\}.$$

$$\gamma = \frac{1}{6720}\left\{-5\Delta_1 - 3\Delta_2 - \Delta_3 + \Delta_4 + 3\Delta_5 + 5\Delta_6\right\}.$$

If the lunar wave be of any importance the harmonic elements of the daily period as deduced from observations in different phases of the moon will show certain *regular* changes. But as the daily period is in itself very variable, and depends on the radiation of the sun at the place of observation, these latter changes must be entirely eliminated before the changes produced by the superposition of the lunar wave can be distinctly recognised.

Judging from my own experiments, I believe that the variation of the daily period, which is due to meteorological changes, forms the most serious obstacle to this investigation. The gravitational deflections of the plumb-line are large enough to be discovered by the horizontal pendulum But it requires a very long set of observations to reduce the meteorological effects sufficiently in the mean results to make the former visible.

In my investigation contained in No. 3169 of the 'Astr. Nachr.' I have availed myself of the three sets of observations, containing 159, 161, and 123 days respectively, of twenty-four readings each.[1] For each day the time of the upper meridian passage of the moon was taken from the almanac, and groups were formed of those days for which C agrees within one hour. Thus, each set of observations was divided into twenty-four groups. If we distinguish these by the letters $a, b, c, d, \ldots, a$, for instance, contained all days with C between 0 hours 0 minutes and 1 hour 0 minutes; d, all days with C between 3 hours 0 minutes and 4 hours 0 minutes; and so on. I then proceeded to form other groups by taking the means $\frac{1}{3}(a+b+c)$, $\frac{1}{3}(b+c+d)$, . . . &c. This was done because the number of days contained in each set of observations was too small to eliminate in a satisfactory manner the irregularities of the curves.

The twenty-four sets of twenty-four mean hourly values each were now treated as described above, the values of β and γ were calculated, and the necessary corrections applied, so as to obtain the purely periodical part P_p of the observations. From the resulting numbers, the harmonic constants a, b were computed, supposing the daily oscillation to be represented by the expression

$$a_1 \cos t + b_1 \sin t + a_2 \cos 2t + b_2 \cos 2t + a_3 \cos 3t + b_3 \sin 3t + a_4 \cos 4t + b_4 \sin 4t,$$

in which t is either Greenwich mean time or local time. A deflection of the plumb-line to the east of its normal position is considered as positive. In deducing the constants a, b account had to be taken of the process of

[1] The readings were taken for the beginning of each hour of Greenwich mean time for the first two sets of observations, and of local time for the third set.

forming groups, certain enlarging factors being applied, as is done in the reduction of tides.

When these results had been obtained it immediately appeared that all the constants down to the smallest terms presented more or less considerable periodic changes. The following table contains two examples, one showing the coefficients of the first harmonic term for Potsdam [1] ($a_1 \cos t + b_1 \sin t$), the second those of the second term for Wilhelmshaven [2] ($a_2 \cos 2t + b_2 \sin 2t$).

C	a_1	b_1	a_2	b_2
H.				
0·5	+10·3	+131·9	+ 89·1	− 0·7
1·5	− 3·1	+135·3	+ 87·7	+15·1
2·5	+ 3·0	+149·9	+ 79·7	+32·9
3·5	+ 2·2	+146·0	+ 58·6	+34·7
4·5	+18·1	+141·2	+ 50·9	+37·8
5·5	+ 9·1	+136·2	+ 31·2	+40·9
6·5	+ 7·0	+137·5	+ 24·7	+33·9
7·5	+10·2	+125·2	+ 14·4	+15·5
8·5	+ 9·4	+109·3	+ 26·6	−13·0
9·5	+ 5·4	+103·6	+ 40·1	−21·2
10·5	+ 7·1	+108·2	+ 69·3	−27·1
11·5	+ 1·9	+110·5	+ 95·4	−25·5
12·5	+12·8	+105·0	+108·3	+ 5·6
13·5	− 1·9	+ 98·0	+109·5	+39·3
14·5	+ 5·2	+ 99·3	+103·2	+53·7
15·5	− 9·9	+102·0	+ 91·8	+52·8
16·5	+ 5·0	+108·1	+ 73·1	+45·8
17·5	− 1·0	+115·6	+ 33·3	+38·5
18·5	+11·4	+126·1	+ 19·9	+33·8
19·5	+14·0	+131·6	+ 5·4	+10·7
20·5	+24·0	+125·5	+ 44·0	−16·2
21·5	+14·2	+125·3	+ 51·8	−38·9
22·5	+ 6·6	+129·2	+ 73·1	−32·4
23·5	+ 6·6	+130·0	+ 77·4	−18·2

Each group from which these numbers were computed contained about twenty days. It is evident that these two periodical changes present an entirely different character. In the first case a_1 and b_1 vary with each other,[3] and the changes are proportional to the mean values of these constants. Putting $m_1 \cos (M_1 - t)$ in place of $a_1 \cos t + b_1 \sin t$, there is no considerable change in M_1. In the second case the changes of a_2 and b_2 are independent of each other, but of about the same range, and the phase is subject to considerable fluctuations. It is immediately seen that the variations in a_2, b_2 are due to the superposition of a lunar wave, which moves on as C changes, whilst the variations in a_1, b_1 may be very nearly represented by a periodical change of m_1 alone.

Similar observations may be made in comparing any of the twenty-four lists of coefficients printed in the 'Astr. Nachr.' There are several cases in which the influence of a lunar term is easily recognised, and others in which it is easy to see that both causes act together to produce periodical changes.

When treating of the daily period it will be shown that the range of

[1] Expressed in units of 0″·0020. [2] Expressed in units of 0″·0028.

[3] This is not quite so evident in the values of a_1 on account of their smallness and irregularity.

motion is on an average very nearly proportional to either the quantity of sunshine or the maximum oscillation of the temperature during the day. Though one might expect that in a series of observations of more than half a year's length, grouped in such a regular way as here, meteorological effects would be sufficiently eliminated, this is really not the case. In comparing the meteorological data with the results mentioned above, it was found that the first class of periodical changes can be explained to a great extent by meteorological changes.

The best way to avoid these disturbing influences would be to place the horizontal pendulum in the bottom of a mine, where the effects of meteorological changes are reduced to a minimum whilst, as far as we may judge, the lunar effects must remain the same as on the surface of the earth.

Since every periodical change in the coefficients a, b can be considered as the combined effect of changes of the first and second kind, it is impossible to decide in the cases of the two stations at Potsdam and Puerto Orotava, where the effects of temperature appear to be especially strong, which part is due to the first, and which to the second, cause. We must content ourselves with the following result: The comparison of the observed temperatures with the harmonic constants of the daily oscillation shows that the former play an important part in producing periodical variations in the latter. But, on the other hand, there is some evidence of the existence of a small lunar wave in both places, amounting to $0''{\cdot}01$, or probably more. I do not hesitate to express the opinion that if it had been possible to continue the observations through a longer interval of time, and thus to eliminate the effects of temperature, a more positive result would have been obtained.

In a former investigation,[1] in which I employed the usual method of tide reduction without having regard to the motion of the zero-point and the variation of the daily period, numerical values of a supposed semi-diurnal wave caused by the moon have been computed. These values agreed pretty well with the formula representing the ordinary gravitational deflections of the plumb-line, for whilst we find the semi-diurnal wave to be

$$+0''{\cdot}0142 \cos(2t-247^\circ{\cdot}5) \text{ and } +0''{\cdot}0128 \cos(2t-228^\circ{\cdot}5)$$

for Potsdam and Puerto Orotava respectively, the formulæ of deflection are:—

$$+0''{\cdot}0099 \cos(2t-270^\circ) \text{ and } +0''{\cdot}0142 \cos(2t-270^\circ).$$

Until further researches have been made, it seems advisable not to place too much confidence in these numbers, though it is not impossible, from the way in which they were computed, that they represent a near approach to the real values.

Whilst we now see that the observations obtained at Potsdam and at Orotava were insufficient to demonstrate the effects of the moon on the plumb-line, the third series of observations at Wilhelmshaven, as might be expected after the preliminary investigation mentioned above, led to a positive result of some interest. It will be shown later on that at Wilhelmshaven, though the range of the daily oscillation is extremely variable, there does not exist such a clear relation between it and the

[1] See *Das Horizontalpendel*, &c. pp. 87–104.

meteorological phenomena as in the two former cases. In consequence the effect of variability of the daily period is much better eliminated, and it makes little difference if, in computing the lunar terms, one takes account of it or not.

The following expression was deduced by a simple transformation from the original values of a, b, after expressing each of the eight series as an harmonic function of C. The form in which it is given is, of course, entirely empirical. Thus the changes in the coefficients, which here depend on C, in reality probably depend on the declination of the moon. All uncertain terms I have suppressed, and only retain those the existence of which is demanded by the observations.

$$\left\{\begin{array}{l} 9{\cdot}5\,(\pm 1{\cdot}12) + 41{\cdot}9\,(\pm 2{\cdot}43)\cos(C - 268^\circ{\cdot}7) \\ \qquad\qquad\qquad + 20{\cdot}8\,(\pm 2{\cdot}25)\cos(2C - 164^\circ{\cdot}1) \\ \qquad\qquad\qquad + 24{\cdot}5\,(\pm 2{\cdot}43)\cos(3C - 260^\circ{\cdot}4) \end{array}\right\}\cos(t - C - 121^\circ{\cdot}8)\,^{1}$$
$$+\{45{\cdot}0\,(\pm 0{\cdot}95) + 10{\cdot}5\,(\pm 1{\cdot}97)\cos(C - 194^\circ{\cdot}8)\}\cos(2t - 2C - 341^\circ{\cdot}3)$$
$$+\{\;9{\cdot}1\,(\pm 0{\cdot}50) + 12{\cdot}1\,(\pm 0{\cdot}71)\cos(2C - 50^\circ{\cdot}9)\}\cos(4t - 4C - 332^\circ{\cdot}0)$$

In comparing the above expression with the lunar term computed by the first simpler method, which is

$$45{\cdot}4\cos(2t - 2C - 345^\circ{\cdot}7),$$

it is seen that it contains a nearly identical term. Considering this alone, we find that it represents a semi-diurnal deflection of the plumb-line, the eastern excursion of which takes place on an average a little more than half an hour *before* the meridian passage of the moon, or about $1\frac{1}{4}$ hour before high water. The observatory lies on the west side of the Fahdebusen, at a distance of about 200 m. from high-water mark, whilst the station for tidal observations is a good deal more to the south, at the entrance of the harbour. Accordingly the semi-diurnal term might be explained in a pretty satisfactory way by the pressure of the tides, which on an average rise to a height of $3\frac{1}{2}$ m. at Wilhelmshaven. This would certainly be a very strong effect of tidal depression compared with the theoretical results obtained by Professor Darwin in his researches; but as the soil is of a marshy character, and apparently very elastic, such an effect would not appear impossible.

The present results, however, seem to tell against such an explanation; for, if it were the tides that produce by their pressure the lunar terms, a close connection between these and the form of the tides ought to be established, which is not the case. In fact, the very large term of the first order, which is perhaps the best determined of all, and which is all the more remarkable, because, according to our computation, it changes the sign, reminds one of the corresponding lunar tide, which, though playing an important part in many places in the world, is comparatively small on the coasts of Germany.

It seems advisable to postpone a discussion of the above facts until further observations undertaken at some suitable place shall have placed them beyond doubt. Perhaps few places in the world would offer a better

[1] Expressed in units of $0''{\cdot}0028$. The numbers in brackets are *approximate* values of the probable errors of the coefficients.

chance for studying the effects of the tides than the Bristol Channel, with its enormous variations of the water-level.

The following formula expresses, in the same unit as above, the ordinary lunar deflection of the plumb-line; and it will be remarked that the latter is very small compared with the observed deflections:—

$$5{\cdot}0 \sin 2\delta \cos (t-270^\circ) + 3{\cdot}7 \cos^2 \delta \cos (2t-270^\circ),$$

where δ is the moon's declination.

As it might be of interest to the reader to be able to judge for himself how far the formula for Wilhelmshaven represents the observations, I have appended the following table of the values of the coefficients a_1, b_1, and a_4, b_4.[1] a_2, b_2 were given above, and the changes in a_3, b_3 are less pronounced, this term being altogether the smallest. The unit is again $0''{\cdot}0028$, and each pair of constants rests on about twenty days of observations.

C	a_1	b_1	a_4	b_4
H.				
0·5	+292·8	+203·0	+ 4·0	+ 6·4
1·5	+298·2	+199·5	+ 2·4	+17·5
2·5	+292·0	+194·6	− 9·0	+18·4
3·5	+271·4	+198·0	−10·8	+15·6
4·5	+249·0	+202·4	−15·8	+ 8·4
5·5	+272·6	+211·5	−16·1	+ 1·3
6·5	+255·6	+221·1	−14·2	+ 1·1
7·5	+277·9	+232·9	− 9·3	+ 4·3
8·5	+261·7	+240·1	− 8·2	+ 5·5
9·5	+270·2	+251·4	−10·1	− 0·7
10·5	+261·5	+249·3	−12·3	− 5·8
11·5	+286·4	+237·2	− 9·4	− 8·1
12·5	+276·1	+208·4	− 3·2	+ 1·0
13·5	+287·8	+192·8	− 0·8	+ 9·8
14·5	+285·2	+191·0	− 7·2	+14·6
15·5	+315·0	+188·1	−15·2	+13·2
16·5	+311·6	+213·5	−17·2	+ 8·1
17·5	+324·8	+233·5	−10·2	+ 5·3
18·5	+307·7	+252·2	− 7·1	+ 2·4
19·5	+313·0	+256·3	− 2·7	+ 4·0
20·5	+277·0	+240·6	−11·4	+ 7·2
21·5	+261·9	+245·3	−17·3	+ 5·8
22·5	+260·7	+232·3	−10·7	− 2·5
23·5	+261·7	+222·7	+ 1·0	+ 0·7

II. *The Daily Oscillation and its Changes.*—The most prominent feature in the curves is a daily oscillation, which, from the agreement between the observations taken at three different places under varied conditions, must be considered as a phenomenon of a universal, and not of a local, character.

If we take the means of all the observations the daily motion of the horizontal pendulum, which, when it is placed in the meridian, represents the east-west component of the motion of an ordinary pendulum, is described in the following table:—

[1] These values refer to Greenwich mean time, whilst in the formula t has been reduced to local time.

Place	West Elongation	Zero	East Elongation	Zero
	" H. M.	H. M.	" H. M.	H. M.
Potsdam . .	(−0·23) 8 30 A.M.	1 0 P.M.	(+0·26) 5 0 P.M.	1 0 A.M.
Wilhelmshaven .	(−1·0) 5 0 A.M.	9 30 A.M.	(+1·2) 3 0 P.M.	8 30 P.M.
Puerto Orotava .	(−0·17) 7 30 A.M.	10 30 A.M.	(+0·23) 4 0 P.M.	9 30 P.M.

The curves representing these daily changes bear a resemblance to the curves of the daily changes of temperature and of magnetic declination. The ordinates for every two hours are as follows:—

Mean Local Time (beginning at noon)	Potsdam	Wilhelmshaven	Puerto Orotava
H.	"	"	"
0	−0·06	+0·82	+0·09
2	+0·13	+1·17	+0·21
4	+0·25	+1·07	+0·23
6	+0·23	+0·62	+0·15
8	+0·16	+0·14	+0·06
10	+0·10	−0·24	−0·02
12	+0·02	−0·55	−0·07
14	−0·06	−0·82	−0·11
16	−0·12	−1·06	−0·14
18	−0·18	−1·01	−0·16
20	−0·24	−0·42	−0·18
22	−0·21	+0·47	−0·09

As was pointed out before, the daily motion of the horizontal pendulum is extremely variable, especially as far as the range of motion is concerned. Whilst the epochs of elongation do not differ much from the mean values within a small number of days, they appear to be subject to an annual change. But owing to the observations being incomplete the character of this annual variation is not sufficiently well-determined. Thus, at Orotava, during four months of observations in winter, we find that in the earlier part (December) the maximum deflections occur about two hours later than towards the end (April). At Wilhelmshaven the eastern elongation is earlier in spring and autumn than in midsummer, whilst at Potsdam there is no very marked change.

The range of motion (α) was found to be much more variable, and it was interesting to compare it with the maximum oscillation of temperature (θ) during the day as well as with the observations on sunshine (S) and clouds (Cl). The following mean results were obtained:—

Potsdam				Puerto Orotava					
α	θ[1]	Cl[2]	No. of Observations	α	θ	No. of Observations	α	S.	No. of Observations
"	°			"	°		"	H.	
0·14	5·7	9·1	10	0·10	5·4	5	0·11	2·3	3
0·30	7·1	8·1	38	0·22	6·5	13	0·24	3·1	8
0·48	9·4	6·5	41	0·35	7·5	25	0·35	4·0	18
0·68	10·4	4·9	31	0·51	8·2	28	0·51	7·1	22
0·87	12·2	3·4	22	0·64	8·5	33	0·64	7·8	30
1·09	14·0	1·5	10	0·76	9·4	14	0·76	8·9	12
				0·88	9·6	4	0·88	9·7	4

[1] Celsius (Centigrade). [2] Clear sky = 0, clouded sky = 10.

WILHELMSHAVEN					
a	θ	No. of Observations	a	θ	No. of Observations
$''$	$^\circ$		$''$	$^\circ$	
1·66	1·5	4	2·25	7·5	22
1·72	2·2	2	2·39	8·4	13
1·90	3·4	4	2·81	9·5	6
2·34	4·5	19	2·95	10·3	8
2·06	5·4	24	2·73	11·3	4
2·31	6·5	28			

We see from these numbers that at Potsdam as well as Orotava the average range of daily motion agrees most remarkably with those meteorological elements which we may consider as a measure of the intensity of solar radiation. But I must not omit to remark that the single days do not show this coincidence equally well. For cloudy days occur with a large range of oscillation, and clear days with a small range.

At Wilhelmshaven, though we find that a similar relation is indicated, it is not so well marked. If we neglect the first three and the last three lines in the above table, which rest on a small number of days only, the range of motion appears to be very nearly constant. It is this circumstance which allowed the lunar wave to be determined with much more accuracy than in either of the two other cases.

The above results make it evident that the daily oscillation is to a great extent due to thermal effects of the sun. Probably there are other causes acting besides, but temperature and radiation are certainly the principal agents. Owing to this fact it would be quite useless to try and study the tidal effects of the sun.

How this thermal effect takes place remains as yet an open question. It seems quite impossible to connect the observed oscillation with purely local influences, such as we constantly observe in our astronomical observatories. It would certainly be a most extraordinary chance if the radiation of the sun should produce such similar effects on the foundations in three places, so entirely different from each other respecting all conditions. I may mention besides that a few observations made at Karlsruhe in 1887 and recent observations by Professor Kortazzi at Nicolaiew show the general character of the curve to be the same in those two places as we have found it. Until further researches have been made, we may therefore consider the daily oscillation of the plumb-line as a general phenomenon all over the surface of the earth, and consequently it would afford great interest to study it at a number of places equally distributed over it and with as varied conditions as possible.

The question naturally arises whether these motions which we must consider as motions of the soil are still noticeable at a certain depth below the surface. We ought not to expect this, according to what has just been said; but, on the other hand, the law of continuity makes it difficult to understand how they should disappear quite near the surface, at a depth down to which the daily change of temperature penetrates, when they are still so noticeable in such a place as the cellar of the Potsdam Observatory.

I have had no chance until now of trying this interesting experi-

ment. But, during the observations at Wilhelmshaven, Professor Boergen at my request had readings taken twice a day of the level of the meridian circle to see if the daily oscillation could be noticed there as well. The result of one month's observations was that there was no appreciable difference.

The pier of the meridian circle rises from a mass of sand, which forms the subsoil of the marshy ground round Wilhelmshaven, down to a depth of more than 250 m. The walls of the observatory as well as the column of the pendulum have their foundation in a layer of clay of 2 m. or 3 m. thickness, which is divided from the sand by a layer of turf-like material, about 1 m. thick. Perhaps, if one does not prefer to attach no importance to the indications of the water level when treating of so small angular quantities, we may conclude from the above result that only the upper layer of clay, which presses on the elastic turf, partakes of the oscillation.

III. *The Motion of the Zero-point.*—Next to the daily oscillation a particular interest is attached to the motion of the zero-point, for by studying it we may hope to learn something about the slow secular changes which we know take place constantly all over the earth, though the number of places is small where they are noticeable to the eye within a small interval of time. For this purpose it is desirable to have an uninterrupted series of observations, or at least, where interruptions are unavoidable, as will probably always be the case with such a delicate instrument, to determine by other means as well as possible the motion of the zero-point during the interval.

I have pointed out before that the present observations, with the exception of those made at Puerto Orotava, are incomplete in this respect, for they were interrupted once in June, and at Wilhelmshaven many days were missed in May. Notwithstanding, some results of interest have been gathered. The daily oscillation having been determined, two numbers were interpolated from the readings for every day, corresponding to the moments when the periodical deflection is equal to zero, and curves were drawn and compared with the curves of temperature and barometric pressure.[1]

(1) At Wilhelmshaven a remarkably strong effect is produced by the changes in the barometer. When the pressure increases the pendulum moves towards the east, thus indicating a sinking of the soil in the same direction, and a change of 1 mm. in the former corresponds with a change of $0''\cdot29$ in the direction of the plumb-line. Apparently both changes take place simultaneously, or, if the changes in the position of the pendulum lag behind those of barometric pressure, the difference must be very small.

Thus, the horizontal pendulum in this particular case acts as a most delicate barometer, and might be used as such if it were not subject to other influences. As the atmospheric pressure presents a daily oscillation, it is necessary in discussing the daily period of the plumb-line to take the former into account.

(2) The correspondence between the pendulum and the barometer is most pronounced when the mean temperature remains pretty constant during a number of days, but with sudden changes of temperature the effect of the latter is seen to prevail over the former. From all the

[1] See the reproduction of a part of these curves in my paper, *Das Horizontalpendel*, &c.

observations, it was concluded by a careful investigation that at Wilhelmshaven a rise of temperature of only 1° C. produces exactly the double effect which is caused by an increase of barometric pressure of 1 mm., viz., a motion of $0''\cdot58$ towards the east.

Thus it is seen that, when these two meteorological agents happen by chance to act in the same sense, very considerable deflections of the plumb-line are produced at Wilhelmshaven, which, in case they should not be limited to the upper layers of the ground, would not escape detection at an astronomical observatory where regular observations are taken.

(3) A similar investigation led to the following results for Potsdam. Barometric pressure appears to have no effect whatever on the position of the pendulum at this place. But a rise of temperature of 1° C. produces a deflection of $0''\cdot16$ towards the east. This latter constant is again determined with considerable accuracy, the result of thirty-eight days in April and May being $0''\cdot18$, whilst fifty-seven days of the later period give the value $0''\cdot15$.

(4) At Puerto Orotava the meteorological effects are small, but they present a particular interest. They are not so easily noticed as in the two former cases, where to see them it is sufficient to look at the diagrams. Nevertheless they exist, and the following values could be deduced by properly grouping the observations. A change of +1 mm. in barometric pressure causes a deflection of $0''\cdot0309$ of the plumb-line to the west, and a change of +1° C. in temperature a deflection of $0''\cdot0362$ to the east.

The effect of barometric pressure is especially interesting, because, from the description of the locality given above, it may be gathered that it could be accounted for by the counteraction of volcanic forces, which undoubtedly are still active inside the Pico de Teyde. If it is allowable to draw any conclusions from the intervals of time in which during the latest centuries volcanic action has shown itself on the outskirts of this famous mountain, the time would now have arrived when the inhabitants might be prepared to see another of those outbursts. It is not improbable that, before an eruption takes place, the whole mass might show an inclination to yield to variations of external pressure. And this is really the case, for Puerto Orotava is situated on the N.N.E. flank of the cone, at a distance of about 18 kilometres; thus, when the external pressure diminishes, the slope of the mountain is increased, and a horizontal pendulum placed as it was at Orotava ought to move towards the east.

(5) It is interesting to compare the effects of temperature, which we have now found to exist, with each other as well as with the daily oscillation. If we divide the mean values of the latter by the mean corresponding values of the maximum oscillation of temperature, we obtain the following table, which corresponds throughout with a change of 1° C.:—

	Zero-point	Daily Oscillation
	$''$	$''$
Wilhelmshaven	0·58	0·36
Potsdam	0·16	0·06
Orotava	0·036	0·06

Thus it is evident that, if it is the same cause which produces the motion of the zero-point and the daily oscillation, this cause acts in a different way and not in the same intensity everywhere. It is necessary

to add that in the present investigation no account has been taken of a purely local effect of temperature which is caused by a difference in the length of the two foot-screws east and west of the pendulum. If they are not equally long, a change of temperature will produce a small tilt of the instrument. This, however, would only be noticeable in the motion of the zero-point, for the daily change of temperature in the cellars was practically zero. But also in the former it would only account for a small motion, such as, for instance, was found for Orotava. Considering the dimensions of the instruments, I find that a difference of temperature of 1° C. produces a tilt of $0''\cdot0164$ multiplied by the difference in the length of the screws expressed in millimetres. The surface of the column which carries the pendulum ought therefore to be made as nearly horizontal as possible, supposing the instrument to possess an entirely symmetrical form.

(6) Besides those changes which we have until now considered, and which by the nature of their causes can never surpass certain limits, the zero-point is subject to others of particular interest, which are probably due to geological causes, viz., the slow folding of the earth's crust. By the aid of the diagrams drawn I have tried to fill out the gaps in the observations, and to construct curves which represent approximately the motion of the zero-point, corrected for temperature and barometric pressure, during the whole period of observation. Starting from an arbitrary zero, I have obtained the following values, in which an increase indicates a motion towards the east, corresponding to a tilt in the same direction:—

Potsdam				Wilhelmshaven				Puerto Orotava			
		″				″				″	
1889 April	1	21·0		1889 March	7	5·5		1890 Dec.	26	5·3	
„	15	13·0		„	15	4·1		1891 Jan.	14	1·1	
May	1	6·8		„	26	4·9		Feb.	1	0·7	
„	9	5·4	W. elong.	April	6	4·1		„	13	0·3	W. elong.
June	1	13·8		„	30	6·7	E. elong.	March	1	1·0	
„	15	16·6	E. elong.	May	20	1·7		April	1	1·9	
July	1	14·2		„	30	1·5		„	27	2·7	
Aug.	1	8·6		June	28	1·5					
Sept.	1	7·0		July	30	2·9					
Oct.	1	2·6		Aug.	14	8·5	E. elong.				
				„	25	5·0					
				Sept.	25	8·2					

In computing the values for Wilhelmshaven I supposed that during the month of June there was no considerable alteration in the position of the zero-point as it is indicated by the form of the diagrams before and after the interruption. The observations at Orotava are complete, whilst at Potsdam the interruption is so short that the given values may be considered as very nearly accurate.

Thus we find that the pendulum showed the greatest motion at Potsdam, where its installation was certainly the most favourable of all. Observations there were commenced about five months after the column was completed. During the whole of April and the first part of May the column inclined towards the west; it then turned and a tilt of $11''\cdot2$ towards the east began, which lasted until the middle of June, when again it inclined towards the west, moving through an angle of $14''$ until the end of the observations.

At Wilhelmshaven, where from other reasons one might have expected a larger motion, the latter is really comparatively small. Two very distinct waves present themselves in the diagrams, both causing maximum excursions to the east on April 30 and on August 14. But on the average the mean position of the pendulum remained pretty constant. This fact is of some importance, considering that the column at Wilhelmshaven had also been constructed five months before the commencement of the observations, and that the heavy moisture of the cellar would in that case certainly retard the process of drying. Thus it is not likely that the strong motion which took place at Potsdam during the first month ought to be ascribed to this cause.

This conclusion would, however, not be justified in the third case, for when observing at Puerto Orotava circumstances did not permit me to lose so much time. If the considerable inclination of the column towards the west during the first month be ascribed to the drying process, the general motion of the zero-point is of a very simple form, and may be explained by a slow tilt towards the east.

It is only natural to suppose that all modern geological changes in the island of Teneriffe emanate from the Peak as a centre. If this is true, the observed tilt might be the consequence of a slow elevation of the island, which would gradually increase the slope of the lower parts of the mountain, and would find an end when the internal forces should again succeed in breaking themselves a way through one of the weaker parts of its flanks.

When considering the interest which is attached to the Canary Islands and the Pico de Teyde, especially in the history of volcanic theories, the foregoing remarks, though only founded on a short series of observations, will suffice to indicate the service which might be rendered to geological science by observing two horizontal pendulums during a sufficiently long interval of time on opposite sides of the mountain cone. Places like Icod de los Vinos, on the north side of the island, and Guimar, on the south side, are probably to be recommended most, for not only do they offer the comfort which is desirable for a longer sojourn, but the surrounding country is so full of interest as to form a most magnificent object for scientific study of the most varied kind.

IV. *Seismological Phenomena and Others.*—Some time before writing this account I drew up a paper containing all observations on seismological phenomena obtained by myself, and lately by Professor Kortazzi at Nicolaiew, up to May 1893. This paper is not yet printed, but will soon be published in 'Petermann's Mittheilungen.' [1] As it is impossible to enter much into details here, I must refer the reader to this paper. Respecting the phenomena of earth pulsations and other remarkable movements of the earth's surface I am in a similar position, for another paper on these, which is illustrated by figures representing some of the most curious portions of the photographs, is about to be published in the 'Astronomische Nachrichten.' [2] In order to avoid repetition I shall in the following remarks include all that may as yet be said about the later observations at Strassburg, as far as it refers to the object of this section.

The horizontal pendulum, besides constantly indicating the position of the plumb-line in relation to the surrounding objects on the earth's surface, affords an excellent means of controlling the momentary state of the

[1] See list of papers, p. 309, No. 15.

[2] See list of papers, No. 14.

soil. This, like the surface of a lake, is sometimes at rest, and at other times subject to undulations and vibrations, which have received the general name of microseismic movements. The horizontal pendulum in its present form offers the same difficulty which is often felt by earthquake observers, viz., that it is often impossible to say whether the disturbances visible on the curves have been produced by vibrations setting the pendulum swinging, or by a repeated tilting. The latter, when it takes place slowly, and when the period of the tilt does not coincide with that of the pendulum, would only produce deflections; but as all microseismic movement appears to be very complicated and variable, probably deflections and swinging of the pendulum generally act together. Thus we may explain the great variety of figures which are seen on the photographs and sometimes extend over several hours, thereby indicating that earthquake motion, when it travels over large distances, spreads out more and more on account of the difference in the rate of propagation. It is well to remember hereby that in a few cases in which the effect of distant earthquakes was observed by astronomers, when they were occupied with the levels of their instruments, the motion was nearly always seen to be of an undulatory character, whilst at the centre of an earthquake vibratory horizontal motion generally prevails.

(1) *Observations of Earthquakes.*—The comparison of the curves obtained simultaneously first at Potsdam and Wilhelmshaven, and later at Strassburg and Nicolaiew, has shown that a very large percentage of the observed disturbances was common to both places. In fact, it is a comparatively rare occurrence that when an earthquake figure, however small, appears on one of the photographs, it is not equally visible on the other. It often happens that the curves are not sufficiently distinct, owing to variations in the intensity and figure of the light-point and faults in the paper, or when a general microseismic movement is more pronounced at one of the stations than at the other. In such cases small disturbances may at first escape detection, but are often found when notice is given from the other station.

The difference of time is well marked in many cases during the observations in 1892–93, whilst in 1889 the distance was too small, considering the uncertainty connected with the readings. The distance between Strassburg and Nicolaiew is nearly 2,000 kilometres, and yet many of the observed disturbances appear to have lost none of their intensity in passing over this distance. We are thus quite justified in expecting that strong earthquakes will be observed by the horizontal pendulum, wherever their centre may be on the earth. Of course it is quite possible that the conditions for propagation are more favourable in certain places than in others, and that, for instance, earth-waves travel more easily across continents than when they have to pass over broad oceanic tracts.

The publication of the entire list of nearly 200 disturbances will, I hope, lead to establish a greater number of relations between some of these and observed earthquakes than I have yet been able to find. Nevertheless, amongst the latter there are some cases of great interest, of which I mention the following: the Japanese earthquakes of Tokio, April 17, 1889, and of Kumamoto, July 28, 1889; the earthquakes of Wjernoje (Central Asia), July 12, 1889, and of Patras in Greece, August 25, 1889; the earthquake of San Francisco, April 19, 1892; several of the Zante earthquakes, and the great Levant earthquake which took place in the town of Malatia on February 9, 1893.

As it is impossible here to describe all these cases in detail I refer to the above paper; only this may be mentioned, that in the case of the great earthquake of Kumamoto two disturbances were observed, which exactly agree with the supposition that the earthquake-wave travelled round both sides of the globe with a velocity of 2·3 kilometres per second.

The time of a shock as obtained by this method is always rather uncertain for two reasons. The first is that, owing to the slow rate of the motion of the paper, which was 11 mm. per hour, the readings may be 2 or 3 minutes in error; the second, that a shock very rarely begins suddenly, but is generally preceded by smaller movements of the ground, which make it impossible to decide which is the beginning of the earthquake. In such cases, however, I have sometimes found the figures of a disturbance to show remarkable coincidences. Thus, by comparing the moments of sudden increase of motion at the two stations, which occur in nearly every earthquake, several determinations of the difference of time may be obtained, the mean of which is affected by a smaller probable error than a single determination.

The velocities of propagation obtained from the above-mentioned observations vary between 2 and 5 kilometres per second, which, however uncertain the single values may be, confirms the view that it is impossible to speak of a *constant of velocity* in the distant propagation of earthquakes.

If the first observations with the horizontal pendulum leave much to be desired with respect to their application to the study of earthquakes, they certainly show what might be done if only a small number of stations, well distributed all over the earth, were organised. It would be a great satisfaction to the writer if this account should help to excite an interest for the establishment of at least one such station in the far West, say in the western part of the United States or Canada, and another in the far East, in Japan, or rather in some other country which is less subject to the effects of local earthquakes. We may safely predict that the comparison of horizontal pendulum curves obtained at two such stations, with those at an intermediate European station, would lead to most interesting results, not only from a seismological point of view, but also with respect to the determination of the modulus of elasticity of the upper strata of the earth. If, with this special object in view, one should not lay any value on observing at the same time the deflections of the plumb-line, the horizontal pendulum might be much simplified, and perhaps an improved form of Milne's 'tromometer' or conical pendulum, when furnished with sufficiently fine corrections, would be the cheapest and simplest instrument. The rate of the paper ought to be much increased, and this could be done without raising the expense, for it would not be necessary to employ a very high degree of sensitiveness, the deflections of the pendulum would thus be reduced, and a narrow strip of paper would be sufficient where a broad sheet is now required.

(2) *Earth Pulsations.*—Earth pulsations, consisting of long, flat waves, somewhat like the swell of the ocean, were for the first time observed by myself at Potsdam on February 11, 1889. Owing to the application of glycerine, as described above, the pendulum could not swing, and a sharp black line was drawn by the light-point. The instrument had been adjusted in the afternoon, but in consequence of some

after-effect the light-point was slowly travelling across the paper. At 7 P.M. waves begin to be visible, which are beautifully distinct between 8.44 and 10.40. The mean period of a wave is about 9 minutes, and the average range is $0''\cdot 1$. The motion disappears gradually, and the curve soon reassumes its ordinary appearance as a dark line of uniform breadth.

This is the only case in which earth pulsations were distinctly observed during the experiments in 1889. The curves at Wilhelmshaven certainly present very large irregularities, and systems of waves of all sorts of periods, from a few minutes up to nearly one hour, appear; but all these disturbances bear a more irregular character. At Potsdam, again, the light-point was rather large, and consequently a broad line was drawn, and it may be that this was the reason why no trace of earth pulsations was ever noticed again, for, when the waves are small, the light-point must not be beyond a certain size in order that the waves may be visible. I may mention, however, that the curves which I obtained when the glycerine arrangement was still in use showed traces of pulsations on many days. The borders of the black line have the appearance of a zigzag, like the teeth of a saw, a tooth on one side corresponding with an interval between two teeth on the other. Thus, it is quite possible that, for the sake of representing such motions as earth pulsations, it would be useful to damp the swing of the pendulum in order to avoid the effect of other microseismic movements, which cause the pendulum to oscillate, and thereby help to increase the breadth of the curves.

On January 5, 1890, earth pulsations first appeared on a photograph taken at Orotava. The period of the waves is much smaller than in the case described above, and they are so close together that it requires a magnifying glass to distinguish and to count them. Beginning at 6.37 A.M., 103 half-oscillations are distinctly seen, which are extremely regular as far as the period is concerned, which is 45 seconds, or $1\frac{1}{2}$ minute for a complete oscillation. The range of motion is variable, and it is easily recognised that several systems of waves are superimposed on each other. The total range of motion is about $0''\cdot 15$ on an average. Afterwards the waves are less distinct; larger deflections interfere and destroy the regularity.

Soon after this observation I heard of some curious phenomena that had been observed at Madeira. The sea had risen and fallen at short intervals on the south coast, whilst on the Desertas Islands large landslips had occurred which caused the breakage of a cable in the neighbourhood. When examining more closely the times of observation, I found that there was certainly no direct connection between these phenomena and the disturbance observed at Orotava on January 5.

Later on it appeared that the latter was not at all extraordinary, for on many days similar disturbances were observed, always at the same time of the day, viz., the time in which the pendulum is in its western elongation. On many days it was possible to count a few waves, but with one exception they were too close together to allow such a detailed investigation to be made as on January 5. This happened on April 7 when thirteen waves, with a period a little more than $7\frac{1}{2}$ minutes each, appeared on the photograph, nearly as distinct as in the case observed at Potsdam. It is interesting to note that, on the system of these waves, which have a range of $0''\cdot 07$, other smaller waves are visible,

the period of which is nearly the same as the period of the waves on January 5.

Amongst the fifty-two days which show traces of this curious phenomenon during the time between 5 A.M. and noon, there are several on which it appears developed into a large disturbance of the character of an earthquake. Whether this is a chance coincidence, and earthquake waves really happened to pass over Teneriffe so often during the same time of the day, is a question which, of course, cannot be answered with certainty. But it is much more probable to suppose that it was only the intensity of the motion, in which these days differed from others, like January 5 and April 7. Thus, if I had possessed the means for observing real tilts, and not the swing of the pendulum on those days, probably very large deflections would have been noted.

It is very interesting to find that this phenomenon bears such a decidedly local character at Orotava, for it *never* occurs at other times of the day than in the early morning and forenoon. It generally begins at a time when there is yet no trace of wind in the lower parts of the island, though this circumstance may not appear of much importance, because from many comparisons made it is nearly certain that the wind exercises no influence whatever over the pendulum. The idea naturally presents itself that the causes which produce the daily oscillation might also be the reason why a certain period of the day is especially favourable to the formation of earth pulsations. If the daily period be the effect of a general motion of the ground, its condition of stress might vary, thus affording the internal forces a better chance of producing such an effect during one part of the day than during the other.

I now turn to the description of some cases of earth pulsations lately observed at Strassburg, but, as the observations are not yet finished, I should like the following remarks to be considered as provisional only. During the whole summer of 1892 photographs were taken, but never did a trace of earth pulsations appear on them. The lines were not as clear as I wished them to be, yet it was easily seen that in a general way the pendulum was remarkably steady compared with what had been noticed at the former stations. About the middle of October a slight change was made in the lamp, which only produced a very insignificant difference in the appearance of the curve.

On October 19 earth pulsations suddenly appeared, such as had never been seen before. The appearance of the curve is as follows  and is due to the imperfect figure of the light-point, which, instead of being a small circle, has an oblong shape, with its axis a little inclined, thus causing one branch of each wave to be more marked than the other. This shows how important it is that the point of light should be as small and as regular in shape as possible. During an interval of nearly ten hours I counted about 200 successive waves, the duration of each being nearly three minutes. At first the period of the waves was a little larger, viz., 3 minutes 19 seconds, whilst towards the end it had gradually diminished to 2 minutes 43 seconds. The amplitude was a little less than $\frac{1}{20}$th of a second, and remained constant throughout, thus giving the zigzag line an extremely regular appearance.

A very similar and yet more remarkable series of earth pulsations was observed on December 22, when more than 300 waves were counted within a period a little shorter than on October 19. Besides these two cases many others occurred when the number of waves was smaller. The mean

period could always be accurately determined by counting the number of the waves within the space of a few hours, and a period of a little less than three minutes was found in most cases. But it is evident that this is not a constant, for occasionally waves with longer periods are observed, and again in some parts of the curve the borders show traces of waves of very short period, like a fine fringe.

The size of these waves is always about the same as above, and they present no such variations as in Puerto Orotava. They generally are visible during several succeeding hours, but often, too, a portion of the curve, which is as undisturbed as a straight line, is broken by a short series of waves.

Towards the end of the winter these earth pulsations seem to have again entirely disappeared. No change of any kind was made in the instrumental arrangements, and the curves are quite as distinct as before. Perhaps a more careful inspection, which will be made when the observations have come to a close, will show traces where they have now been overlooked; but certainly nothing like the two cases mentioned above has occurred during the last four or five months.

At Tokio Professor Milne has observed earth pulsations, which differ from the above, because their period is only a few seconds. But in a photograph which he has lately sent me I find a zigzag line of quite the same form as described above; thus it is certain that waves of longer period occur in Japan also.

The study of earth pulsations may prove to be of importance for many branches of scientific research. For instance, they may explain some curious discrepancies which are occasionally noticed in astronomical observations. If it should be found by future observations that waves representing an angular value of a few tenths of a second are a frequent occurrence, astronomers will be forced to take them into account, and will no longer be able to rely on the present method of determining the level in all delicate researches.

(3) *Earth Tremors.*—A third appearance of interest in the curves is what is generally called earth tremors. Perhaps they are nothing else than earth pulsations of short period, but I prefer to think that they are principally due to the swinging of the pendulum, produced by small vibrations and pulsations, which now increase and now again retard its motion. Such tremors generally last many hours, and sometimes days, and the curve, which is often like a dark black line drawn by a ruling pen, takes the appearance of a succession of small earthquake figures. When roughly comparing the results obtained at Potsdam and Wilhelmshaven, I found that strong tremors were nearly always observed at both places simultaneously, and that they bear a relation to the force of the wind. When strong wind is blowing tremors may always be expected to occur, and sometimes they appear to outrace the wind, for they are also noticed in calm weather when there is wind at a distance. The intensity of tremors is not always proportional to the strength of the wind. No systematical comparison, however, has yet been made, because of the many interruptions at Wilhelmshaven and the short duration of the observations.

At Puerto Orotava tremors were quite insignificant; in fact, there is scarcely a trace of them, except during the hours when earth pulsations occur. This is all the more remarkable because heavy winds are constantly blowing against the high mountain chain in the island, but perhaps they would have been more noticeable if observations had been

taken in the east-west plane, and not in the plane of the meridian, which is nearly at right angles with the mountains and the coast line. For this reason, perhaps, no effect was either noticed of the heavy surf which is for ever beating against the rocky coast.

At Strassburg tremors were also found to be considerably smaller than at either of the first two stations. During the warmer season the light-point appears to be much more steady than in winter, and altogether strong tremors are a rare occurrence. A special investigation will be made when the observations have come to an end.

For an investigation of the earth pulsations and tremors little only can be done with the present arrangement of the apparatus, which only offers a means of studying the statistics of these phenomena. It is necessary to use quickly moving paper and plates and a highly sensitive pendulum in order to make the details visible. As the soil is often perfectly steady through long intervals of time, to avoid taking useless photographs a telescope ought to be added, through which it is possible to see whether the pendulum is at rest or not.

(4) *Sudden Deflections of the Pendulum.*—I have already mentioned that the curves at Wilhelmshaven are so full of irregularities that some parts may be compared with declination photographs of magnetic storms. But whilst these are seen more or less every day, the following disturbances are amongst the rarest occurrences.

On April 9, 1889, at 6.36 P.M., the light-point at Potsdam suddenly travelled through $8\frac{1}{2}$ mm., which is equal to a deflection of $0''\cdot34$ of the plumb-line towards the west, thus forming the following figure . It is evident that this deflection was *not instantaneous*, for if it had been so, the curve would have appeared broken, the second part beginning with swings, as is the case whenever a deflection of the pendulum is caused artificially. But here there is no trace of swinging, and the dark appearance of the line joining the two parts of the curve is a proof that the light-point moved sufficiently slowly to leave an impression on the paper.

Many small deflections are seen on other days at Potsdam as well as at Wilhelmshaven. Amongst those observed at the latter place the most important took place at 11 A.M. on August 9, and at 6.30 P.M. on September 24. They are similar to the case described above, but the line which joins the two parts of the curve is not so well marked, and the following figure is formed . Another remarkable case was observed at Puerto Orotava on February 2, soon after 9 P.M., the figure being as follows . The angular value of the deflection is $0''\cdot17$, but in this case it lasted 1 hour 20 minutes before the light-point had gained its new position, and the middle part of the figure is just as dark as the rest.

Whilst the above deflections were permanent, passing deflections occurred at Wilhelmshaven, and were especially marked on July 12 at 7 A.M., and on September 12 at 6 P.M. In the latter case the

following figure  appears, and the deflection is equal to an angle of not much less than one second in the direction of the plumb-line.

At Strassburg no strong deflections of a similar kind were noted except during some earthquakes and when observations were made at the transit circle, which is borne by the column to which the pendulum is attached. These disturbances must be ascribed to vibrations of the pillar, which are produced either by the earthquakes or by the observer knocking against it, and which cause a slight change in the connection between the pivots and agate cups of the pendulum. It remains, however, to be explained why these displacements so often accompany earthquakes at Strassburg, whilst they were never noticed at any one of the first three stations, although earthquake-motion of probably equal strength was frequently observed there. Besides, it is remarkable that once when a piece of iron was driven into the pillar on the side opposite to where the pendulum was placed, thus causing very considerable vibrations, the displacement of the light-point was not larger than that which accompanied one of the earthquakes.

Observations at Strassburg.—When I returned from Teneriffe I was anxious to continue the observations, but being myself unable to look after the instrument I sent it to Professor Kortazzi, who wished to try it at the Imperial Naval Observatory at Nicolaiew, and has been taking observations in different positions of the pendulum since the spring of last year. At the same time I applied to Professor Becker, the Director of the Strassburg Observatory, who very kindly offered to take charge of the other instrument which had remained at Wilhelmshaven and to place it in one of the cellars of the observatory.

Before this was done the pendulum passed through the hands of Messrs. Repsold. It received new pivots, and the plane mirrors, which I had used before, were replaced by concave silvered glass mirrors of nearly 1 m. focal distance. In making this change I followed the advice of Dr. Eschenhagen at Potsdam, who had obtained beautifully sharp curves with these mirrors. A circular mirror was cut in two, and one half was ground down as much as possible to reduce its weight. But through this process the focal length was slightly changed, and when the two halves were afterwards placed one over the other it was impossible to make the two reflected points of light equally sharp. At first the silvered surface was soon spoiled through the moisture, but when the mirrors had been resilvered and the ordinary precautions were taken to dry the air inside the pendulum box, this difficulty was removed, and the same mirrors have been in use without interruption since last July. Though the curves obtained at Strassburg are certainly finer than the older ones, I am not sure that the same result might not be obtained by using the ordinary plane mirrors if these were silvered on the front side. Besides it must be remembered that the distance between the mirror and the photographic paper had to be reduced to more than one-half of the former distance, which alone ensures a sharper image, and that it is very difficult to make two such mirrors with exactly the same focal length when the latter is large.

In placing the instrument it was considered to be of special interest to attach it to one of the large pillars of the observatory. The pillar of the transit circle was selected and a stone table fixed into it on its east side,

because I wished to take observations in the east-west plane. The lamp and photographic apparatus are mounted on wooden tables, and the distance between the pendulum mirror and the drum is a little less than 2 m. The necessary preparations were made in November 1891, but regular observations did not begin until April 1892. At first many interruptions occurred owing to the extraordinary motions of the zero-point, which caused me to discontinue the observations for a few days at the beginning of May. A second interruption occurred in June, because it was necessary to have the mirrors resilvered; but since July 18 last until now the instrument has been in good working order, and only on two occasions the continuity of the observations is broken by sudden motions, which caused the light-point to travel beyond the borders of the paper before it could be noticed at the usual control. To finish the account of the instrumental arrangement, I have to add that since November paper from the manufactories of Dr. Stolze in Charlottenburg has been used instead of Morgan and Kidd's paper, and that a great improvement has thus been obtained owing to its much greater sensitiveness.

For the details respecting the first part of the observations between April 4 and September 18, 1892, I refer to the 'Astronomische Nachrichten,' No. 3147. The discussion of the later observations, together with a general investigation, has been deferred until later, because it is intended to continue the series up to the beginning of September. For this reason I am unable here to give definite results, and shall only mention what may be of use to other observers.

The daily period is much smaller than it was found when the pendulum was placed in the meridian, but it is well pronounced, and, to judge from the aspect of the curves alone, it decreases much in winter. During the winter months it entirely disappears on some days. The same fact has been communicated to me as observed at Nicolaiew by Professor Kortazzi. The diagram representing the daily change is much like the one which I found from one day's eye observations at Karlsruhe in 1887, and forty-eight days' observations at Nicolaiew in 1892 give a similar result. The following numbers I extract from the 'Astronomische Nachrichten,' + denoting a deflection towards the north:—

M.T. (0 hour = noon)	Karlsruhe 1887	Strassburg 1892	Nicolaiew 1892
Hours	″	″	″
0	+0·086	+0·017	+0·040
2	−0·065	−0·016	+0·024
4	−0·151	−0·057	+0·003
6	−0·200	−0·079	−0·016
8	−0·184	−0·064	−0·030
10	−0·192	−0·034	−0·037
12	−0·108	−0·011	−0·037
14	−0·016	+0·015	−0·029
16	+0·135	+0·050	−0·010
18	+0·225	+0·073	+0·013
20	+0·237	+0·065	+0·035
22	+0·204	+0·041	+0·045

Thus it is seen that at Strassburg the plumb-line is in its southern elongation about 6 P.M. and in its northern elongation about 6 A.M. These epochs, however, only represent the mean of the summer months. At Nicolaiew the times of these moments are each about four hours later.

The general form of the true oscillation of the plumb-line is probably very nearly represented by an ellipse whose large axis lies between the two directions E.W. and N.W.–S.E.

The daily oscillation of the pendulum at Strassburg is quite insignificant when compared with the enormous changes of the zero-point. During the first fortnight, when a change of 1 mm. in the position of the light-point was equivalent to a deflection of 0″·027 of the plumb-line, the pendulum was moving towards the north. Between April 4 and 18 it travelled through 6″·4,[1] when it stopped, and a southward motion began, which was very considerable during the whole of last summer, for the following angles were described:—

		″	
Between April 18	and May 5	−14·36	(motion south)
„ May 8	„ June 1	−13·12	„
„ July 18	„ July 27	−10·45	„
„ July 27	„ Sept. 2	−10·55	„
„ Sept. 2	„ Sept. 18	− 7·34	„

The same motion continued with a varying rate and occasional stoppings during the rest of the year 1892 and the beginning of 1893. The total angular displacement is probably very nearly 2 minutes when the intervals are taken into account during which observations were missed. Since the early months of this year a reaction seems to have taken place, for a slow northerly motion has commenced, and now and then the pendulum remains in very nearly the same position during several days. I believe that the extraordinary motion of the pendulum, which far exceeds anything one could have expected beforehand, considering its favourable foundation, is due to two causes—a very considerable tilt of the column from the north to the south and a large annual oscillation which augments the southerly motion during the later part and retards it during the earlier part of the year.

If the tilting is due to a general motion of the ground it must affect the meridian circle, which is at a short distance to the east of the transit instrument. A comparison will be made as soon as the nadir observations are available. In November 1892 Professor Becker had a water level attached to the other side of the pillar, which was read twice a day. As it is a well-known fact that water-levels are not very reliable for this sort of observations, it will not be surprising to hear that the readings of the level, although they agree in a general way with the motion of the pendulum, differ from it in many details.

The temperature of the cellar is read twice a day because it is subject to considerable variations. Owing to the form of the building of the meridian circle, in which the instruments are placed one storey high, the cellars below the observing rooms are not underground, and in winter during the severe cold the temperature fell below zero (C.). An effect of temperature is certainly indicated, and will require a careful examination.

It may be mentioned that the pillar which carries the transit instrument, and to which the pendulum is attached, is not massive throughout. A horizontal section through the middle of it presents the following figure $\oplus$. The cylindrical mantel stands *on the same* foundation as the middle part, and is probably rigidly connected with it in its lower and

[1] When speaking of the angular motion of the pendulum the corresponding motion of a vertical pendulum is always meant.

upper parts. If one considers these circumstances it does not appear improbable that the pendulum might be affected by temperature in a different way from the level on the other side.

The large motion of the pendulum is felt as a great drawback when it is necessary to give it a high degree of sensitiveness, because it requires a constant watching of the light-point in order to make the necessary corrections before it leaves the paper. But another difficulty arises, because when a strong motion of the pillar takes place in the N. S. direction it is only natural to suppose a similar motion to take place in the E. W. direction, which must cause a perpetual change in the scale value.

During the observations at Strassburg the period of the pendulum was observed every now and then, and as it had not varied much at first, observations were taken at longer intervals afterwards. On May 10, however, when a new determination was made by Professor Becker with the chronograph, it was found that the period, which had been 12·4 seconds (one-half swing) before, had risen to 17·4 seconds, which indicates that either the pillar had been tilted considerably from the west to the east, or that a sudden displacement of the pendulum must have taken place, perhaps during one of the earthquake-shocks, the effects of which were mentioned above.

Should other observers try the horizontal pendulum they may gather from the above that it is almost necessary to use a double pendulum for observing both components of the deflections, and that arrangements should be made to determine the period of oscillation at short intervals whenever a strong motion of the zero-point is indicated.

During the winter a curious fact was communicated to me by Professor Kortazzi. In trying to explain the motion of the zero-point he had placed a hygrograph in the cellar with the pendulum, and found that the pendulum was decidedly influenced by the relative moisture of the air in the cellar, for the diagrams were much like each other. In a letter to me he expressed the following opinion. The column which carried the pendulum had been piled up of large loose stones without mortar or cement in order to be able to begin the observations without the loss of time caused by the drying process. The ground of the cellar being perfectly dry, it appears that the stone behaved like a sponge, drawing in the moisture contained in the air more or less, and thereby causing a change in the inclination of the instrument. I have lately heard from Professor Kortazzi that the effect of moisture disappeared almost entirely when the openings through which the cellar communicated with others were closed, and the pillar was covered with a waterproof material.

It is evident that if this cause has a considerable effect at Nicolaiew, it could only have been of secondary importance at the other stations. At Wilhelmshaven, for instance, the relative moisture of the air was probably always 100 per cent. It is necessary, however, to consider this agent also, and to take the necessary precautions in order either to avoid or to eliminate its effect as much as possible in the final results. A dry and wet bulb thermometer have therefore been placed in the cellar at Strassburg, and are read twice every day.[1]

[1] It may be useful to mention that observations with two horizontal pendulums, exactly like the one used by myself, are now being made by Prof. Lewitzky at Charkow.

The Action of Magnetism on Light; with a critical correlation of the various theories of Light-propagation. By JOSEPH LARMOR, *M.A., D.Sc., F.R.S., Fellow of St. John's College, Cambridge.*

[A communication ordered by the General Committee to be printed among the Reports.]

PART I.—MAGNETIC ACTION ON LIGHT.

Discovery of Magnetic Rotation.

1. THE reduction of light and heat, and of electrical phenomena, to a common cause has been a cardinal subject of physical speculation from the earliest times. More recently Oersted [1] fully persuaded himself, on somewhat wider knowledge of fact, 'that heat and light are the result of the electric conflict,' and saw in his great discovery of the gyratory action of an electric current on a magnet the explanation of the phenomena classed under the name of polarisation of light. But it was reserved for Faraday to make the first effective entrance into this domain of knowledge.

2. After failure in 1834 to discover any direct relation between light and static electrification, and after repeated attempts in other directions, he at length discovered [2] the fact that when plane polarised light is passed through a transparent body along the direction of lines of magnetic force, its plane of polarisation undergoes rotation by a specific amount characteristic of the medium traversed. He thus succeeded 'in magnetising and electrifying a ray of light, and in illuminating a magnetic line of force.' After observing that when the ray is oblique to the lines of magnetic force it is the component of the force in the direction of the ray which appears to be effective in producing the rotation (a law which has since been exactly verified by Verdet and more recently by Du Bois), he proceeds to inquire into the condition of the active medium with the following results:

'2171. I cannot as yet find that the heavy glass when in this state, *i.e.*, with magnetic lines of force passing through it, exhibits any increased degree, or has any specific magneto-inductive action of the recognised kind. I have placed it in large quantities, and in different positions, between magnets and magnetic needles, having at the time very delicate methods of appreciating any difference between it and air, but can find none.

'2172. Using water, alcohol, mercury, and other fluids contained in very large delicate thermometer-shaped vessels, I could not discover that any difference in volume occurred when the magnetic curves passed through them.'

The rotation was in general right-handed with respect to the magnetic force; and in the case of (2165) 'bodies which have a rotative power of their own, as is the case with oil of turpentine, sugar, tartaric acid, tartrates, etc., the effect of the magnetic force is to add to, or subtract from, their specific force, according as the natural rotation and that induced by

[1] Hans Christian Oersted, *Experimenta circa Effectum conflictus Electrici in Acum Magneticam*, Hafniae, 1820.

[2] M. Faraday, *Experimental Researches*, 19th series; *Phil. Trans.*, 1845.

the magnetism is right or left handed.' (2187.) 'In all these cases the superinduced magnetic rotation was according to the general law, and without reference to the previous power of the body.'

Further on, after describing the diversity of the effect in different media, and its usually small amount in crystals, he adds:

'2182. With some degree of curiosity and hope, I put gold-leaf into the magnetic lines, but could perceive no effect. Considering the extremely small dimensions of the length of the path of the polarised ray in it, any positive result was hardly to be expected.'

The powerful rotation discovered long after by Kundt, with films of iron, will here be called to mind.

Repeated trials with various transparent media gave no effect of lines of electro-static force on a ray of polarised light, propagated either along them or at right angles to them. An effect in this case has been detected by Kerr long after, but presented itself as a change in the elasticity, producing double refraction, and entirely devoid of rotational character.

'2224. The magnetic forces do not act on the ray of light directly and without the intervention of matter, but through the mediation of the substance in which they and the ray have a simultaneous existence.'

Any such changes of internal constitution of media must of necessity (2226) 'belong also to opaque bodies: for as diamagnetics there is no distinction between them and those which are transparent. The degree of transparency can, at the utmost, in this respect only make a distinction between the individuals of a class.'

After pointing out (2230) that this is 'the first time that the molecular condition of a body, required to produce the circular polarisation of light, has been artificially given,' and is, on that account also, worthy of minute study, Faraday proceeds to draw out in very clear and striking contrast the distinction between the natural undirected rotatory property of liquids like turpentine, and the magnetic property which is related to the direction of the lines of force, as well as the distinction between the latter and the axial but undirected rotatory power of quartz.

This brief *résumé* of the topics treated in Faraday's memoir will be of interest as indicating how thoroughly he probed the problem, and how much his ideas were on the lines of the subsequent development of the subject.

Mathematical Representations of the Phenomena.

3. The rotation of the plane of polarisation in quartz and other substances had already been explained by Fresnel as depending on the two principles, (i) that the vibrations which can be propagated without change of form as they proceed are for these substances circular (or it may be elliptical), and (ii) that the velocity of propagation is different according as the vibration runs along in the manner of a right-handed or a left-handed screw-motion. It had also been shown by MacCullagh[1] how such properties might be deduced from equations of vibration modified by the insertion of small terms involving $(d/dz)^3$, where z is the direction of propagation.

Soon after Faraday's discovery of magnetic rotation, Airy[2] pointed out the different modifications of the equations of vibration that would similarly account for the existence of the magnetic rotation.

[1] J. MacCullagh, *Trans. R.I.A.*, xvii. 1836; *Collected Works*, pp. 63, 186.
[2] G. B. Airy, *Phil. Mag.*, June 1846.

We may in fact develope a complete and compact account of the matter, as follows. The equations for the displacements in a circular transverse vibration, propagated along the axis of z, are

$$u=A\cos(nt-ez),\ v=A\sin(nt-ez);$$

for a given value of z these equations represent a circular vibration in the plane of xy, and this is propagated in spiral fashion as a wave. We may very conveniently combine the two equations into one by use of the vector $\vartheta=u+\iota v$ to represent the displacement, thus obtaining the form

$$\vartheta=Ae^{\iota(nt-ez)}.$$

As this vibration is propagated without change, the equation of propagation must be linear in ϑ, therefore of the form

$$\frac{d^2\vartheta}{dt^2}=a^2\frac{d^2\vartheta}{dz^2}+P.$$

The terms in P involve higher differential coefficients, and are necessary in order that the two values of e corresponding to a given value of n may not be equal except as to sign, in other words in order that right-handed and left-handed waves of the same period may be propagated at different speeds. To ensure this result, P must contain terms of odd order in the differential coefficients; if there were only terms of even order, it would still lead to an equation for the square of e, and so would represent ordinary dispersion without the rotational property.

If we confine our attention to terms of the first and third orders we can tabulate possible rotational terms as follows: [1]

$$\kappa_1\frac{d^3\vartheta}{dz^2dt},\quad \kappa_2\frac{d^3\vartheta}{dt^3},\quad \kappa_3\frac{d\vartheta}{dt},\quad \kappa_4\frac{d^3\vartheta}{dzdt^2},\quad \kappa_5\frac{d^3\vartheta}{dz^3},\quad \kappa_6\frac{d\vartheta}{dz}.$$

Now in the case of the first three types, change of sign of z does not affect the phenomenon; thus the rotation is in the same direction whether the wave travels forward or backward; it is of the magnetic kind. In the case of the last three types, change of sign of z produces the same effect as change of sign of the rotatory coefficient; the rotation is of the kind exhibited by quartz and sugar and other active chemical compounds.

On an ultimate dynamical theory, if ϑ denote displacement in a medium of density ρ, $\rho\dfrac{d^2\vartheta}{dt^2}$ will represent force per unit volume; and the principle of dimensions shows that κ_1/ρ, κ_2/ρ, κ_3/ρ, are respectively of dimensions $[L^2T^{-1}]$, $[T]$, $[T^{-1}]$, in length and time. Thus the coefficient κ_1 will produce rotation owing to some influence of a distribution of angular momentum pervading the medium; while the coefficients κ_2 and κ_3 would produce selective rotation owing to the influence of the free periods of the fine-grained structure of the imbedded atoms of matter. The latter kind of rotation is to be expected to a sensible amount only in the rare cases in which selective absorption of the light is prominent; consequently we are guided, as a first approximation, to ascribe magnetic rotation to a coefficient of the type κ_1.

The last three types of term will be appropriate to represent the rotation of naturally active media. The dimensions of κ_4/ρ, κ_5/ρ, κ_6/ρ,

[1] J. Larmor, *Proc. Lond. Math. Soc.*, xxi. 1890.

are respectively [L], [L^3T^{-2}], [LT^{-2}]. The term actually employed by MacCullagh to illustrate that action was the statical one with κ_5 for coefficient.

Dynamical Illustrations.

4. The first direct dynamical investigation bearing on the subject is by Lord Kelvin.[1] He points out that the elastic reaction of a homogeneously strained solid has a character essentially devoid of all helicoidal and of all dipolar asymmetry. It therefore follows that the helicoidal rotation of the plane of polarisation by quartz, turpentine, etc., must be due to elastic reactions dependent on the heterogeneity of the strain through the space of a wave.

Then with regard to the magnetic or unipolar rotation the well-known paragraph occurs, quoted by Maxwell ('Treatise,' § 831) as 'an exceedingly important remark,' of which his own theory of molecular vortices, and also its outcome, the conception of the working model which led to the electric theory of light, is an expansion. On reversing the light the magnetic rotation is not reversed: therefore it depends on some outside influence of a vector character, exerted on the system which transmits the light. This influence makes the free period of a circular motion differ, according as it rotates in one direction or the opposite one. If the purely elastic forces maintaining the motion are supposed similar in the two cases, it will follow that 'the luminiferous circular motions are only components of the whole motion.' There must be another dynamical system present, linked with the one which transmits the light, and possessing motion of rotation round the lines of magnetic force, or some other motion directed with respect to those lines; and the kinetic reaction between these two systems will account for the magnetic rotation.

The influence which is exerted on the free periods of a vibrating system by linking it on to another system which is in rotation may be illustrated by some dynamical problems. If the angular velocity of the rotating system is supposed to be maintained constant, such illustrations admit of comparatively simple analytical treatment. We can determine the change produced by the rotation in the free period of the original system. If that system is one member of a chain or solid continuum, we can deduce the velocity of propagation of waves of given length from a knowledge of this change of period; for it is the velocity which would carry the undulation over a wave-length in the free period. A typical example of this kind, which is treated in the paper, is the motion of a Blackburn's pendulum, suspended from a horizontal bar which is made to spin round a vertical axis with angular velocity ω. The equations of motion are

$$\frac{d^2x}{dt^2}-\omega^2x-2\omega\frac{dy}{dt}=-\frac{g}{l}x;$$
$$\frac{d^2y}{dt^2}-\omega^2y+2\omega\frac{dx}{dt}=-\frac{g}{m}y.$$

Writing

$$n^2=\frac{1}{2}\left(\frac{g}{l}+\frac{g}{m}\right),\text{ and }\lambda^2=\frac{1}{2}\left(\frac{g}{l}-\frac{g}{m}\right),$$

[1] W. Thomson, 'Dynamical Illustrations of the Magnetic and the Helicoida Rotatory Effects of Transparent Bodies on Polarised Light,' *Proc. Roy. Soc.*, 1856.

the motion for the case when ω is very great compared with n loses its original character, and reduces to a form which, neglecting slight tremors, is derived approximately from the superposition of two circular motions, one in the same direction as the angular velocity ω, of period $2\pi/\sigma$, the other in the opposite direction, of period $2\pi/\rho$, where

$$\rho=n+\frac{1}{8}\frac{\lambda^4}{\omega^2 n}-\frac{1}{8}\frac{\lambda^4}{\omega^3},\ \sigma=n+\frac{1}{8}\frac{\lambda^4}{\omega^2 n}+\frac{1}{8}\frac{\lambda^4}{\omega^3}.$$

The rotation in such a case as this becomes dominant; a plane oscillation now subsists, but will rotate steadily round the axis with angular velocity $\frac{1}{2}(\sigma-\rho)$, which is the slower the greater the velocity ω with which the horizontal arm is carried round.

These results may be extended to any rotating system with two transverse principal periods. Thus for the case of a long stretched cord, or a long rod, rotating round its own length with an angular velocity ω which is very great compared with either of its natural transverse frequencies $(2\pi/l)^{-\frac{1}{2}}$ and $(2\pi/m)^{-\frac{1}{2}}$, the period of vibration of a wave of given type on the rotating cord will be changed to

$$\frac{2\pi}{n}\left(1+\frac{1}{8}\frac{\lambda^4}{\omega^2 n^2}\right)^{-\frac{1}{2}};$$

and the angle of rotation of its plane of polarisation, during propagation through a wave-length, will be

$$\frac{\pi\lambda^4}{4n\omega^3},$$

this rotation being in the same direction as the angular velocity ω.

Again, this æolotropic cord may have imposed on it such a (slight) rate of twist that a very long plane wave, made helicoidal by the rotation ω, will just be straightened out again by this twist, as it progresses along the cord, the natural period being still practically unaltered. From this remark it follows that 'the effect of a twist amounting to one turn in a length s, a small fraction of the wave-length, is to cause the plane of vibration of a wave to turn round with the forward propagation of the wave, at the rate of one turn in $8\frac{n^4}{\lambda s^3}$ wave-lengths,' in the same direction as the imposed twist.

The first of these results illustrates magnetic rotation, the second the axial rotation of quartz; while a medium filled with spiral arrangements, like the second but devoid of special orientation, represents the rotation of turpentine. The mode of passing directly in this illustration from the effect of spin to the effect of helical structure produced by twist is noteworthy.

The subject of a vibrating chain loaded with gyrostats, having their axes all along it, is considered by Lord Kelvin in a later paper:[1] and the general behaviour, as to propagation of waves, of a chain loaded with gyrostats which are orientated in any orderly manner with respect to it, has also been developed.[2]

[1] W. Thomson, *Proc. Lond. Math. Soc.*, vi. 1875.
[2] J. Larmor, *Proc. Lond. Math. Soc.*, xxi. 1890.

Mathematical Representations tested by Verdet's Experiments on Magnetic Dispersion.

5. The use of the term of type κ_1 to explain magnetic rotation was arrived at by Maxwell[1] by the help of a provisional theory of molecular vortices, in which it occurs as standing for the reaction of a vortical motion of the medium representing its magnetisation, when that motion is disturbed by the light-vibrations passing through it.

A very full examination has been made by Verdet[2] of the manner in which the constant of magnetic rotation (hence called Verdet's constant) depends on the direction of the ray with regard to the magnetic force, on the refractive power of the medium, on the dispersive power of the medium, and in the same medium on the wave-length of the light. The rotation comes out, as has since been verified in detail by Du Bois, to be proportional simply to the component of the magnetic force along the ray. Media of great refractive power have in general high magnetic rotatory power. For the same medium the product of the rotatory power and the square of the wave-length is nearly constant, but always increases slightly with the index of refraction; media of great dispersive power have in general also high rotatory dispersion.

Verdet's most important piece of work is, however, a precise comparison of his experimental numbers for different wave-lengths with the results of a mathematical formula adapted to express both ordinary dispersion and the magnetic rotation according to Maxwell's theory. He assumes Cauchy's form of the ordinary dispersion terms, and so obtains equations equivalent to

$$A_0 \frac{d^2\vartheta}{dz^2} + A_1 \frac{d^4\vartheta}{dz^4} + \ldots = \rho \frac{d^2\vartheta}{dt^2} + 2C\gamma\iota \frac{d^3\vartheta}{dz^2 dt},$$

from which is derived (Maxwell, 'Treatise,' §§ 828–830) the formula connecting θ, the rotation, with m, a specific constant for the medium; γ, the magnetic force resolved along the ray; c, the length of path of the ray on the medium; λ, the wave-length of the light in air; and i, the index of refraction of the medium. This formula is

$$\theta = mc\gamma \frac{\iota^2}{\lambda^2} \left(i - \lambda \frac{di}{d\lambda} \right).$$

The comparison with experiment leads to agreement within the possible errors of observation (Maxwell, *loc. cit.*) for the case of bisulphide of carbon, but for the ordinary creosote of commerce the agreement is not so good. The fact that creosote is a chemically complex substance, or rather a mixture of different substances, may be of influence here.

A coefficient of the type κ_2 leads also to the general law of proportionality to the inverse square of the wave-length, but does not correspond nearly so well in detail as κ_1; a coefficient of the type κ_3 (C. Neumann's) must be rejected altogether.

It is to be borne in mind that it is only in substances with regular dispersion that Cauchy's dispersive terms can be taken to represent the facts; whereas the κ_2 rotatory term is, as we have seen, related to a free period of some kind in the system, and therefore to abnormal dispersion.

[1] J. C. Maxwell, *Phil. Mag.*, 1861; *Treatise*, § 822, *seq.*

[2] E. Verdet, *Comptes Rendus*, 1863; *Annales de Chimie* (3), lxix.; in *Œuvres*, vol. i. p. 265.

6. The considerations just given bring together evidence of various kinds, that for ordinary media the κ_2 rotatory term is to be taken as very subordinate to the κ_1 term. Using the κ_1 term alone, the equations of propagation of a wave travelling along the lines of magnetic force (now leaving out dispersion) will be of the form

$$\rho \frac{d^2u}{dt^2} = a^2 \frac{d^2u}{dz^2} + \kappa_1 \frac{d^3v}{dz^2dt};$$

$$\rho \frac{d^2v}{dt^2} = a^2 \frac{d^2v}{dz^2} - \kappa_1 \frac{d^3u}{dz^2dt}.$$

Let us now attempt to deduce general equations of propagation along any direction. These clearly must involve three constants $\kappa_x, \kappa_y, \kappa_z$ proportional to the components of the magnetic field along the axes of coordinates. For they must lead to the experimental law that the rotation for any direction of the wave is proportional to the component in that direction of the intensity of the magnetic field; in particular this law must be satisfied for the directions of the axes of coordinates. Further, the vibrations may be assumed to remain purely transverse, so that we must have no compression of the medium; and therefore the condition

$$\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = 0$$

is to remain satisfied after the rotational terms are added to the equations.

The equations, then, must for an isotropic medium conform to the general type

$$\rho \frac{d^2u}{dt^2} = \mathrm{A} \nabla^2 u + \mathrm{B} \frac{d}{dx}\left(\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz}\right) + \frac{d}{dt} \mathrm{P}_x,$$

in which P_x, P_y, P_z are linear functions of the second spacial differential coefficients of the displacements; and transversality of the unmodified wave requires $\mathrm{A}+\mathrm{B}=0$. Further when w, $\frac{d}{dx}$ and $\frac{d}{dy}$ are all null, these functions must reduce to the forms

$$\kappa_z \frac{d^2v}{dz^2}, \quad -\kappa_z \frac{d^2u}{dz^2}, \quad 0.$$

Hence

$$\mathrm{P}_x = \kappa_z \frac{d^2v}{dz^2} - \kappa_y \frac{d^2w}{dy^2} + \mathrm{Q}_x,$$

in which Q_x involves only products of $\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}$.

Transversality of the disturbed wave requires

$$\frac{d\mathrm{P}_x}{dx} + \frac{d\mathrm{P}_y}{dy} + \frac{d\mathrm{P}_z}{dz} = 0;$$

hence changing the expression for P_x to

$$\mathrm{P}_x = \left(\kappa_x \frac{d}{dx} + \kappa_y \frac{d}{dy} + \kappa_z \frac{d}{dz}\right)\left(\frac{dv}{dz} - \frac{dw}{dy}\right) + \mathrm{R}_x,$$

R_z can involve only products of the operators $\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}$, and we must have identically

$$\frac{dR_x}{dx}+\frac{dR_y}{dy}+\frac{dR_z}{dz}=0.$$

These conditions necessitate that R_x, R_y, R_z shall be each null.

The equations of the magnetically modified medium are therefore restricted to a definite form by the hypothesis that the wave remains strictly transversal. The equations so obtained, of the type

$$\rho\frac{d^2u}{dt^2}=A\nabla^2u+B\frac{d}{dx}\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)$$
$$+\frac{d}{dt}\left(\kappa_x\frac{d}{dx}+\kappa_y\frac{d}{dy}+\kappa_z\frac{d}{dz}\right)\left(\frac{dv}{dz}-\frac{dw}{dy}\right),$$

contain only terms that are invariantive for transformation of the coordinates; they thus retain the same form when referred to new axes. They therefore satisfy Verdet's law, that the rotatory coefficient for any other direction, which may be taken as the new axes of z, is proportional to the component of the magnetic field in that direction, as they ought to do.

Not only so, but Verdet's law *requires* that the equations shall be expressible in terms of invariants of the three vectors

$$(\kappa_x, \kappa_y, \kappa_z), \left(\frac{d}{dx}, \frac{d}{dy}, \frac{d}{dz}\right), \text{ and } (u, v, w),$$

independently of particular axes of coordinates. Hence P_x, P_y, P_z must be so expressible; and they must be the components of a vector, of the first degree in the first and third of the above vectors, of the second degree in the remaining one. The invariants which can enter are simply the geometrical relations of the figure formed by the above three vectors drawn as rays from an origin. The only possible forms are the scalars

$$\begin{vmatrix} \kappa_x & \kappa_y & \kappa_z \\ \frac{d}{dx} & \frac{d}{dy} & \frac{d}{dz} \\ u & v & w \end{vmatrix},$$

$$\frac{d^2}{dx^2}+\frac{d^2}{dy^2}+\frac{d^2}{dz^2}, \kappa_x\frac{d}{dx}+\kappa_y\frac{d}{dy}+\kappa_z\frac{d}{dz}, \frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz},$$

and the vectors of which the x components are

$$\kappa_y w-\kappa_z v, \frac{dv}{dz}-\frac{dw}{dy}.$$

These combine to give the most general form for P_x, represented by the equation

$$P_x=L\left(\frac{d^2}{dx^2}+\frac{d^2}{dy^2}+\frac{d^2}{dz^2}\right)\left(\kappa_y w-\kappa_z v\right)$$
$$+M\left(\kappa\frac{d}{dx}+\kappa_y\frac{d}{dy}+\kappa_z\frac{d}{dz}\right)\left(\frac{dv}{dz}-\frac{dw}{dy}\right)$$

$$+N\left(\kappa_y\frac{d}{dz}-\kappa_z\frac{d}{dy}\right)\left(\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}\right)$$

$$+G\left\{\left(\kappa_z\frac{d}{dz}-\kappa_z\frac{d}{dx}\right)\left(\frac{dv}{dx}-\frac{du}{dy}\right)-\left(\kappa_y\frac{d}{dx}-\kappa_x\frac{d}{dy}\right)\left(\frac{du}{dz}-\frac{dw}{dx}\right)\right\}.$$

Now

when $w, \frac{d}{dx}, \frac{d}{dy}$ are null, $P=-\kappa_z\frac{d^2v}{dz^2}$;

„ $v, \frac{d}{dx}, \frac{d}{dz}$ „ $P=\kappa_y\frac{d^2w}{dy^2}$;

„ $u, \frac{d}{dy}, \frac{d}{dz}$ „ $P=0$;

hence $L-M=1$, $G=0$.

This expression for P_x with the correlative ones for P_y and P_z is the most general form which the magnetic terms can assume in an isotropic medium, independently of any condition of exact transversality of the vibrations: transversality requires in addition that L and N shall be null.

The equations of vibration of an elastic medium loaded with spinning molecular gyrostats, whose axes follow the rotations of the elements of the medium, have been formed,[1] and it is of interest to observe that the rotatory terms come under this special type for which L, N are null as well as G. The reason is clear: the action of the gyrostats depends solely on the rotations of the elements of the medium, while the terms involving L and N have no rotational character.

7. Before application of these magneto-optic terms to problems of reflexion at a magnet, the type of the unmodified equations of propagation of light, to which they are to be added, must first be settled. The form of these equations which gives most satisfactory results for reflexion at the interface separating transparent media is (equivalent partially to Lord Kelvin's labile æther theory) expressed most simply both as to bodily equations and as to boundary conditions by the principles of the electro-magnetic theory of light; and it has been shown that the introduction of electric conducting quality into these equations gives a tolerable account of the phenomena of metallic reflexion.[2] It is therefore natural to add on these rotatory terms to the equations of the electro-magnetic theory, and to try to explain the phenomena of magnetic reflexion by their aid, with the boundary conditions appropriate to that theory. This is what has been done in all attempts that have had any success; though there is room for diversity in the electrical basis which has to be supplied for the rotational terms.

Dynamical Theories based on the Form of the Energy-function.

8. The subject of magnetic rotation has been treated by G. F. Fitz-Gerald[3] from the point of view of an additional magneto-optic term in the energy-function of the electro-magnetic medium. According to

[1] J. Larmor, *Proc. Lond. Math. Soc.*, xxii. 1891.

[2] *Cf.* J. J. Thomson, 'Recent Advances in Electricity and Magnetism,' 1893, §§ 352, *seq.*

[3] G. F. FitzGerald, 'On the Electro-magnetic Theory of the Reflection and Refraction of Light,' *Phil. Trans.*, 1880.

theory, the energy of this medium is made up of the kinetic or electromagnetic part T, and the static part W, where in Maxwell's notation, $d\tau$ being an element of volume,

$$T=\frac{1}{8\pi}\int(a\alpha+b\beta+c\gamma)d\tau,$$

$$W=\frac{1}{2}\int(Pf+Qg+Rh)d\tau;$$

and there is also in our problem to be added on another small term, Maxwell's hypothetical magneto-optic part T′.

Now the dynamical equations of any medium or system are most fundamentally expressed as the conditions that the characteristic function of Lagrange and Hamilton

$$\int(T+T'-W)dt$$

should be stationary for a given time of motion from any one definite configuration to another, subject to whatever restraints the coordinates have to obey. This form is the most fundamental, because the processes of the Calculus of Variations are purely analytical, and quite independent of whatever specifying quantities we may choose in order to represent the state of the system, the only condition being that the function $T+T'-W$ is to be expressed in terms of a sufficient number of measures of configuration and their first differential coefficients with respect to the time, and is to be of the second degree as regards these differential coefficients.

In order to obtain such an expression FitzGerald proposes to treat (α, β, γ) as velocities corresponding to coordinates (ξ, η, ζ), so that

$$(\alpha, \beta, \gamma)=\frac{d}{dt}(\xi, \eta, \zeta),$$

and then

$$T=\frac{\mu}{8\pi}\int\left(\frac{d\xi^2}{dt^2}+\frac{dy^2}{dt^2}+\frac{d\zeta^2}{dt^2}\right)d\tau;$$

and this will be successful if W can be represented in terms of (ξ, η, ζ) only. Now in a dielectric

$$4\pi\frac{df}{dt}=\frac{d\gamma}{dy}-\frac{d\beta}{dz}, \ldots, \ldots,$$

hence

$$4\pi f=\frac{d\zeta}{dy}-\frac{d\eta}{dz}, \ldots, \ldots;$$

also (P, Q, R) is, from the constitution of the medium, expressed in terms of (f, g, h) by the linear equations of electrostatic induction, so that the thing required is done. If, in fact,

$$W=\int U d\tau,$$

where U is a quadratic function of (f, g, h), the equations of motion in non-rotational media are involved in the variational equation

$$\int dt\left\{\frac{\mu}{8\pi}\delta\int\left(\frac{d\xi^2}{dt^2}+\frac{d\eta^2}{dt^2}+\frac{d\zeta^2}{dt^2}\right)d\tau-\delta\int U d\tau\right\}=0,$$

for variations of (ξ,η,ζ) subject to the *imposed* condition

$$\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}=0,$$

which expresses that the magnetic flux is constrained to be circuital. This condition is included, in the Lagrangian manner, by adding on to the above variation, which is equated to zero, a term

$$\int dt\ \delta\int\lambda\left(\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}\right)d\tau,$$

and determining λ afterwards as a function of position, so that the imposed condition shall be satisfied. Thus we have

$$\int dt\left\{\frac{\mu}{4\pi}\int\left(\frac{d\xi}{dt}\frac{d\delta\xi}{dt}+\ .\ .\ .\right)d\tau-\int\left(\frac{dU}{df}\delta f+\ .\ .\ .\right)d\tau\right.$$
$$\left.+\int\lambda\left(\frac{d\delta\xi}{dx}+\ .\ .\ .\ \right)d\tau\right\}=0.$$

Changing from the differential coefficients of $\delta\xi$ to $\delta\xi$ itself by integration by parts, and similarly for $\delta\eta$ and $\delta\zeta$ in the usual manner, we obtain finally

$$\frac{1}{4\pi}\int dt\left\{\int\left(\mu\frac{d^2\xi}{}+\frac{d}{dy}\frac{dU}{dh}-\frac{d}{dz}\frac{dU}{dg}+4\pi\frac{d\lambda}{dx}\right)\delta\xi d\tau+\ .\ .\ .\ +\ .\ .\ .\right.$$
$$\left.+\int\left(\frac{dU}{dh}\,\delta\eta\,-\,\frac{dU}{dg}\,d\zeta-4\pi\lambda\delta\xi\ \right)l d S+\ .\ .\ .\ +\ .\ .\ .\right\}=0.$$

This is to be true for all forms of $\delta\xi$, $\delta\eta$, $\delta\zeta$, which necessitates equations of the type

$$\mu\frac{d^2\xi}{dt^2}+\frac{d}{dy}\frac{dU}{dh}-\frac{d}{dz}\frac{dU}{dg}+4\pi\frac{d\lambda}{dx}=0$$

throughout the medium; while at an interface, supposed for an instant to be normal to the axis of x, so that $(l, m, n)=(1, 0, 0)$, we must have

$$\frac{dU}{dh}\delta\eta-\frac{dU}{dg}\delta\zeta-4\pi\lambda\delta\xi$$

continuous.

Now from the bodily equations we deduce at once

$$\nabla^2\lambda=0\,;$$

therefore λ is mathematically the potential function of a mass-distribution on the interfaces only, and so is continuous across them. It follows that the only way of securing the required continuity at an interface is (i) to postulate that η and ζ are continuous across it, owing to the continuous structure of the system, and that therefore $\frac{dU}{dg}$ and $\frac{dU}{dh}$ are also continuous across it; and (ii) either to postulate that $\delta\xi$ is constrained to be null or else that λ is null all over it. The alternative taken in Maxwell's electrodynamics is that λ is null everywhere in the field, as in fact representing no observed physical phenomenon; then the boundary conditions are four, that the tangential components of the magnetic force are continuous, as also the tangential components of the electric force.

Since $(\dot{\xi}, \dot{\eta}, \dot{\zeta})$ is the magnetic force, the displacement of the medium, as represented by the vector (ξ, η, ζ), is in the plane of polarisation of plane-polarised light: by representing it by some function of (ξ, η, ζ), *e.g.*, its curl, we could have it at right angles to this plane, as in Fresnel's work.

This quantity λ is not introduced in FitzGerald's analysis of the problem of ordinary crystalline refraction. As the results of the discussion of propagation and reflexion show, any motion propagated in a medium, homogeneous or heterogeneous, whose dynamical properties are determined by the above characteristic function, is effectively of a compressionless character, and there is no necessity to introduce a restriction to that type. But the case becomes different when magneto-optic terms are added to the energy-function.

9. FitzGerald goes on to assume, after Maxwell's theory of molecular vortices, that the magneto-optic part of the energy is of the form

$$\mathrm{T}' = 4\pi \mathrm{C} \int \left(\frac{d\xi}{d\theta} \frac{df}{dt} + \frac{d\eta}{d\theta} \frac{dg}{dt} + \frac{d\zeta}{d\theta} \frac{dh}{dt} \right) d\tau,$$

where $\dfrac{d}{d\theta}$ denotes differentiation along the lines of imposed magnetic force; but on working out the variation of the characteristic function, he finds a difficulty about satisfying all the equations of condition at an interface. This may, I think, be got over by introducing the undetermined multiplier λ of the above analysis into the variation, and so taking into account a certain condensational tendency which is originated at the interface, and propagated throughout the medium with very great velocity. There also remains for settlement the question whether the energy represented by T' is correctly localised by its formula, or whether it involves superficial components, in addition to the bodily distribution; in Maxwell's vortex theory, from which it is taken, it has been transformed by integration by parts. So long as this doubt remains we shall not be in a position to demonstrate boundary conditions by this method.

A chief interest, at the present date, of FitzGerald's paper, lies in the application of the method of Least Action to deduce the equations of a dielectric medium from the expression for its energy alone. This method would not be available for a medium which is the seat of viscous forces;[1] consequently the equations for a conducting medium would have to be derived from those of a dielectric by the empirical introduction of appropriate terms to represent the viscosity. It is, in fact, clear that the scientific method, in forming a dynamical theory, is to restrict it in the first instance to systems in which the interaction of stress and motion has free play, without the interference with its results that is produced by frictional agencies. The subject of the reduction of the equations of electrodynamics into the domain of the general principle of Least Action has recently been treated by von Helmholtz.

10. The second of the questions raised above will now be examined. The magneto-optic energy must in reality be localised in space and not on surfaces; and it is of interest to inquire what is the most general formula that can be given for it which will lead to terms of the accepted type in the equations of motion. If we take a term in the variational

[1] It is possible, however, to introduce Lord Rayleigh's dissipation function into the general equation of Action.

equation of motion of the form $\int \frac{d^3\phi}{ds^2dt}\,\delta\psi\,d\tau$,—where ϕ and ψ each stand for one of the symbols ξ, η, ζ, and s stands for one of the symbols x, y, z,—and if we trace backwards the operation of integration by parts by which it was derived from the characteristic function, we obtain the following types under the sign of volume-integration which may exist in the direct variation of that function:

$$\frac{d^2\phi}{dsdt}\frac{d\delta\psi}{ds},\quad \frac{d\phi}{dt}\frac{d^2\delta\psi}{ds^2},\quad \frac{d\phi}{ds}\frac{d^2\delta\psi}{dsdt},\quad \phi\frac{d^3\delta\psi}{ds^2dt}.$$

These expressions may combine into complete variations of terms of any of the types

$$\frac{d^2\phi}{dsdt}\frac{d\psi}{ds},\quad \frac{d\phi}{dt}\frac{d^2\psi}{ds^2},\quad \phi\frac{d^3\psi}{ds^2dt}.$$

Now the term in the energy which comes from the linking of the optical with the magnetic motion should be of the first degree as regards the velocities of each of them; and it may involve linear and angular displacements, but not their differential coefficients, *i.e.*, it should involve only second differential coefficients with respect to space. The first of these types is thus the only one available, and the term in the energy must therefore be a scalar constructed from the combination of $\frac{d}{dt}$ with

$$\frac{d}{d\theta}(\xi, \eta, \zeta), \text{ and } (f, g, h) \text{ or } \left(\frac{d\eta}{dz}-\frac{d\zeta}{dy}, \ldots, \ldots\right),$$

if we exclude the scalar

$$v=\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz},$$

which would introduce compression. The term under investigation may therefore have the form either

$$f\frac{d^2\xi}{d\theta dt}+g\frac{d^2\eta}{d\theta dt}+h\frac{d^2\zeta}{d\theta dt}$$

or

$$\frac{d\xi}{d\theta}\frac{df}{dt}+\frac{d\eta}{d\theta}\frac{dg}{dt}+\frac{d\zeta}{d\theta}\frac{dh}{dt},$$

excluding, for the reason already given, forms such as

$$v\frac{d}{dt}(\alpha f+\beta g+\gamma h).$$

Of these the first combines together the angular *distortion* of the medium, the velocity representing the motion in the magnetic field, and the rate of change of the velocity of the medium in the direction of that motion; while the second combines the *spin* of the medium with the velocity in the magnetic field. It would be difficult to assign a physical basis to the former on either a dynamical or an electric theory; and thus we are confined on our premisses to Maxwell's form as giving correctly the localisation of the magneto-optic part of the energy. This dynamical conclusion if granted will restrict the purely formal results of § 6, in the

same way as has been already done by the use of the hypothesis of absolutely perfect incompressibility in the resulting equations of propagation.

11. To discuss the first question it will be convenient to reproduce the main lines of FitzGerald's analysis, with however the introduction of the new terms involving λ, the origin of which has been already explained. The variational equation of the motion is

$$\int dt\left\{\frac{\mu}{8\pi}\delta\int\left(\frac{d\xi^2}{dt^2}+\frac{d\eta^2}{dt^2}+\frac{d\zeta^2}{dt^2}\right)d\tau-\delta\int \mathrm{U}d\tau\right.$$

$$+4\pi\mathrm{C}\delta\int\left(\frac{d\xi}{d\theta}\frac{df}{dt}+\frac{d\eta}{d\theta}\frac{dg}{dt}+\frac{d\zeta}{d\theta}\frac{dh}{dt}\right)d\tau$$

$$\left.+\delta\int\lambda\left(\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}\right)d\tau\right\}=0,$$

in which $\frac{d}{d\theta}=\alpha\frac{d}{dx}+\beta\frac{d}{dy}+\gamma\frac{d}{dz}$, where (α, β, γ) is the imposed uniform magnetic field, $4\pi\,(f, g, h)$ is the curl of (ξ, η, ζ) as defined above, and λ is a function of (x, y, z), analogous to a hydrostatic pressure in a dynamical theory, and to be determined afterwards as circumstances dictate. The variation is conducted in the ordinary manner; and of the final result the term involving $\delta\xi$ is here explicitly set down, for the special case of an isotropic medium for which

$$\mathrm{U}=\frac{2\pi}{\mathrm{K}}\left(f^2+g^2+h^2\right),$$

as follows, l, m, n being the direction cosines of the normal to the element of surface $d\mathrm{S}$:

$$\int dt\left[\frac{1}{4\pi\mathrm{K}}\int\left\{n\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)-m\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)\right\}\delta\xi d\mathrm{S}+\mathrm{C}\int\frac{d}{d\theta}\left(n\frac{d\eta}{dt}-m\frac{d\zeta}{dt}\right)\delta\xi d\mathrm{S}\right.$$

$$-\mathrm{C}\int(l\alpha+m\beta+n\gamma)\frac{d}{dt}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)\delta\xi d\mathrm{S}-\int l\lambda\delta\xi d\mathrm{S}$$

$$+\frac{1}{4\pi}\int\left\{\mu\frac{d^2\xi}{dt^2}+8\pi\mathrm{C}\frac{d^2}{d\theta dt}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)\right.$$

$$\left.\left.+\frac{1}{\mathrm{K}}\left[\frac{d}{dy}\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)-\frac{d}{dz}\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)\right]+4\pi\frac{d\lambda}{dx}\right\}\delta\xi d\tau\right].$$

Thus the bodily equations of propagation are of type

$$\mu\frac{d^2\xi}{dt^2}=-\frac{1}{\mathrm{K}}\left[\frac{d}{dy}\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)-\frac{d}{dz}\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)\right]$$

$$-8\pi\mathrm{C}\frac{d^2}{d\theta dt}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)-4\pi\frac{d\lambda}{dx}.$$

From them comes $\nabla^2\lambda=0$, showing that λ is mathematically the potential function of a mass-distribution on the interfaces only, and so does not appear at all in an infinite homogeneous medium.

The interfacial conditions are most easily expressed by taking for the instant the axis of z at right angles to the element of surface considered.

The following expression must then be continuous across the interface in order that the surface integral may be null :

$$\left\{\frac{1}{K}\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)+4\pi C\frac{d^2\eta}{d\theta dt}-4\pi C\gamma\frac{d}{dt}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)\right\}\delta\xi$$
$$-\left\{\frac{1}{K}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)+4\pi C\frac{d^2\xi}{d\theta dt}+4\pi C\gamma\frac{d}{dt}\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)\right\}\delta\eta$$
$$-\left\{\lambda+4\pi C\gamma\frac{d}{dt}\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)\right\}\delta\zeta.$$

Now we must have $\delta\xi$ and $\delta\eta$ continuous to avoid a breach in the medium at the interface, therefore the coefficients of these quantities must also be continuous across the interface ; and as regards the third term either $\delta\zeta$ is continuous, or else its coefficient must vanish.[1] The other conditions of continuity do not allow $\delta\zeta$ to be continuous ; therefore the third term gives simply the surface condition as to λ in the form

$$\lambda=-4\pi C\gamma\frac{d}{dt}\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right).$$

This very slight pressure λ is by the previous analysis continuous across the interface ; it is important because it appears in a rotationally active form in the equations ; the formula shows that, at the interface, it is proportional to the normal component of the magnetic force.

It appears therefore that we have here a consistent scheme of equations of reflexion and refraction, without the necessity of condoning any dynamical difficulties in the process, the result being in all respects implicitly involved in the expression for the energy function of the medium.

The introduction of the circumstance of conduction, or absorption of the energy of vibration, can hardly affect the analytical form of the boundary conditions as to displacement and traction across an interface. If this be allowed, the problem of reflexion at a magnet will involve the same equations of propagation in the magnet as the above, with the exception that the velocity constant is complex, both the magneto-optic terms and the boundary conditions being otherwise unaltered. How far this theory can compete with others in giving a full explanation of our experimental knowledge would take too long time at present to inquire ; but the considerations to be explained in the latter part of this paper will, I think, give it strong claims to being a correct formulation of the phenomena.

[1] The difficulty has been raised that this procedure leaves $\delta\zeta$ discontinuous, and so apparently leads to rupture of the media at the interface. The reply to this point would be that if the necessity of the continuity of $\delta\zeta$ is admitted, the very formulation of the problem will involve innate inconsistency, as no other equation of condition can be introduced into the variational equation ; while on the other hand the vanishing of the coefficient of $\delta\zeta$, as above, shows that there is no resistance offered to stretching along the normal of the layer of the medium at the interface, and therefore the continuity of $\delta\zeta$ will be actually adjusted by a stretching of the interfacial layer which involves no dynamical consequences. The part of $\delta\zeta$ to be thus adjusted is very small, depending on C ; the mode of adjustment would probably be more fully in evidence, if we passed to the limit through a medium of slight compressibility. Precisely the converse mode of adjustment is in fact required in Lord Kelvin's labile æther. In any case we can hold to the axiom (§ 24) that the variation of the Action introduces all the conditions that are really essential.

Recent Electrical Theories.

12. A recent very comprehensive memoir[1] by Drude, on this subject, begins by alluding to the enormous rotatory power of magnetised bodies discovered by Kundt, which places in strong light the direct magnetic origin of the phenomenon of rotation, and to the observation of Kundt that a film of non-magnetic metal deposited on a magnet destroys Kerr's phenomena, so that they cannot be due to magnetic rotation in the air. He also remarks on the insufficiency of the notion that before reflexion the light penetrates slightly into the magnet and so undergoes rotation in its substance; this notion is in the first place not precise or quantitative at all, and further it assigns to the surface layer of transition an influence in reflexion which is much too great in view of other optical phenomena.

He then takes up one type of the formal equations of propagation in an isotropic medium, viz. (u, v, w) being a certain vector (the rotation in an isotropic elastic medium)

$$\frac{d^2}{dt^2}(u, v, w)=\epsilon\nabla^2(u, v, w);$$

and he works out as follows the results of adding on to the right-hand side terms of the various kinds originally suggested by Airy. On adding terms of the form which represents the theory of C. Neumann, viz.

$$\begin{vmatrix} b_1 & b_2 & b_3 \\ \frac{du}{dt} & \frac{dv}{dt} & \frac{dw}{dt} \end{vmatrix}$$

there come equations of the type

$$\frac{d^2u}{dt^2}=\epsilon\nabla^2u+b_3\frac{dv}{dt}-b_2\frac{dw}{dt}+\frac{d\lambda}{dx},$$

to which the term $\frac{d\lambda}{dx}$ is conjoined in order to allow us to have

$$\frac{du}{dx}+\frac{dv}{dy}+\frac{dw}{dz}=0,$$

i.e., in order that the light-waves shall remain purely transversal.

The form of this new term might be derived from the general variational equation of motion of the system, worked out subject to this limitation of the displacement (u, v, w).

On writing

$$(\xi, \eta, \zeta)=\left(\frac{dw}{dy}-\frac{dv}{dz}, \frac{du}{dz}-\frac{dw}{dx}, \frac{dv}{dx}-\frac{du}{dy}\right)$$

there follows

$$\nabla^2\lambda=-\left(b_1\frac{d\xi}{dt}+b_2\frac{d\eta}{dt}+b_3\frac{d\zeta}{dt}\right),$$

and also the equations of propagation in the form

$$\frac{d^2}{dt^2}\nabla^2u=\epsilon\nabla^2\nabla^2u-\frac{d}{dt}\left(b_1\frac{d\xi}{dx}+b_2\frac{d\xi}{dy}+b_3\frac{d\xi}{dz}\right).$$

[1] P. Drude, 'Ueber magneto-optische Erscheinungen,' *Wied. Ann.*, xlvi. 1892.

Since (b_1, b_2, b_3) are small we may employ in the terms containing them the approximate values of (ξ, η, ζ) which neglect the rotatory action, viz., which satisfy $\left(\frac{d^2}{dt^2}-\epsilon\nabla^2\right)(\xi, \eta, \zeta)=0$, and so obtain finally, for disturbances of period $2\pi/\tau$, the equations

$$\frac{d^2u}{dt^2}=\epsilon\nabla^2u+\frac{\epsilon}{\tau^2}\frac{d}{dt}\left(b_1\frac{d\xi}{dx}+b_2\frac{d\xi}{dy}+b_3\frac{d\xi}{dz}\right).$$

Thus for a wave travelling along the axis of z

$$\frac{d^2u}{dt^2}=\epsilon\frac{d^2u}{dz^2}+\frac{\epsilon b_3}{\tau^2}\frac{d^3v}{dz^2dt}$$

$$\frac{d^2v}{dt^2}=\epsilon\frac{d^2v}{dz^2}-\frac{\epsilon b_3}{\tau^2}\frac{d^3u}{dz^2dt};$$

but the rotatory effect given by these equations, if sensible for waves of moderate length, would be quite insensible for light-waves.

On the other hand, if we add rotational terms of the type employed by Maxwell we should have similarly

$$\frac{d^2u}{dt^2}=\epsilon\nabla^2u+b_3\frac{d^2v}{dz^2dt}-b_2\frac{d^2w}{dy^2dt}+\frac{d\lambda}{dx},$$

where the condition for transverse undulations determines λ by the equation

$$\nabla^2\lambda=-\frac{d}{dt}\left(b_1\frac{d^2\xi}{dx^2}+b_2\frac{d^2\eta}{dy^2}+b_3\frac{d^2\zeta}{dz^2}\right),$$

so that

$$\frac{d^2}{dt^2}\nabla^2u=\epsilon\nabla^2\nabla^2u+\frac{d}{dt}\left\{b_3\frac{d^2}{dz^2}\left(\frac{d\zeta}{dx}-\frac{d\xi}{dz}\right)-b_2\frac{d^2}{dy^2}\left(\frac{d\xi}{dy}-\frac{d\eta}{dx}\right)\right\}$$
$$-\frac{d^2}{dxdt}\left(b_1\frac{d^2\xi}{dx^2}+b_2\frac{d^2\eta}{dy^2}+b_3\frac{d^2\zeta}{dz^2}\right),$$

that is,

$$\frac{d^2}{dt^2}\nabla^2u=\epsilon\nabla^2\nabla^2u-\frac{d}{dt}\left(b_1\frac{d^3\xi}{dx^3}+b_2\frac{d^3}{dy^3}+b_3\frac{d^3\xi}{dz^3}\right).$$

Thus the equations arrived at in these two ways are not, as Drude seems to hastily assume without examination, of the same type.

It is however difficult to see why equations arrived at in this manner are worthy of the detailed discussion and refutation to which Drude subjects them: though it is to be said that they agree formally with the equations of the earliest attempt to explain magnetic reflexion, that of Lorentz based on the Hall effect. The form of the rotational terms in the first of them (leaving out of account the character of the coefficient $\epsilon b_3/\tau^2$) is the same as the one to which we have been already guided as the correct type, by various lines of argument; and in fact the equations adopted by Drude himself are obtained by adding on these terms, somewhat empirically, to the ordinary electro-magnetic equations of type

$$\frac{d^2u}{dt^2}+\epsilon\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)=0.$$

It may be observed that the analysis here given would apply equally if the equations just written were substituted for the fundamental equations from which it started.

13. The electrical views by means of which Drude accounts for the addition of terms of this kind to the electro-magnetic equations are as follows. He starts with the two circuital relations to which the equations of electrodynamics have been reduced by Heaviside, Hertz, and other expositors, of the types

$$4\pi u=\frac{d\gamma}{dy}-\frac{d\beta}{dz}, \qquad -\frac{da}{dt}=\frac{dR}{dy}-\frac{dQ}{dz},$$

in which as usual (u, v, w) is total electric current, (α, β, γ) is magnetic force, (a, b, c) is magnetic induction, and (P, Q, R) is electric force. To these equations we would, under ordinary circumstances, add relations depending on the structure of the medium, in the form for isotropic media,

$$(a, b, c)=\mu\,(\alpha, \beta, \gamma),$$

$$(u, v, w)=\left(\frac{K}{4\pi}\,\frac{d}{dt}+\sigma\right)\ (P, Q, R),$$

where K is specific inductive capacity and σ is specific conductivity. To introduce the magnetic rotatory property, Drude proposes to modify the second set of circuital relations 'on Maxwell's analytical basis, that to the kinetic energy of the medium which is expressed in simple form by means of the components of the magnetic force certain subsidiary terms are appended; as according to Maxwell the magnetisation is to be considered as a kind of molecular vortex or concealed motion (*verborgene Bewegung*).' The modification which he assumes on this ground is a replacement of the second circuital relation by one of type

$$-\frac{da}{dt}=\frac{dR}{dy}-\frac{dQ}{dz}+\frac{d^2}{dydt}\,(b_2\,P-b_1\,Q)\,-\frac{d^2}{dzdt}\,(b_1\,R-b_3\,P),$$

keeping the other equations unaltered.

On forming the expression for the transfer of energy per unit volume of the medium, there is obtained (*neglecting*, however, the magneto-optic energy) the equation

$$\frac{d}{dt}\left\{\frac{1}{2}\,\mu\int(\alpha^2+\beta^2+\gamma^2)\,d\tau+\frac{K}{8\pi}\int(P^2+Q^2+R^2)d\tau\right\}$$

$$=-4\pi\sigma\int(P^2+Q^2+R^2)\,d\tau$$

$$+\int\left\{b_1\left(Q\,\frac{dR}{dt}-R\,\frac{dQ}{dt}\right)+\ .\ .\ .\ +\ .\ .\ .\ \right\}d\tau$$

$$+\int\left\{\left(P+b_3\frac{dQ}{dt}-b_2\frac{dR}{dt}\right)\beta-\left(Q+b_1\frac{dR}{dt}-b_3\frac{dP}{dt}\right)\alpha\right\}ndS$$

$$+\ .\ .\ .\qquad +\ .\ .\ .,$$

in which $d\tau$ is an element of volume, and the three integrals at the end are extended over the boundary of the medium, of which (l, m, n) are the direction cosines.

For periodic vibrations there is thus no dissipation of energy except

that due to conduction. But at the interface between two media the transmission of energy without accumulation on the surface requires that, the axis of x being assumed normal to the interface for the moment, in addition to the continuity of (β, γ) the tangential magnetic force, we must have continuity in

$$\left(Q+b_1\frac{dR}{dt}-b_3\frac{dP}{dt},\quad R+b_2\frac{dP}{dt}-b_1\frac{dQ}{dt}\right).$$

The tangential electrical force is therefore to be taken discontinuous; and the author enters into explanations to minimise the repugnance which may be felt to such a hypothesis, their gist being that the part of the electric force derived from the relations of the system itself must be continuous, but the part imposed from without need not be so.

The weak point in this determination of the boundary conditions is the fact that, as the extra terms are supposed to have their origin in a new term in the energy, this term ought to have been included in the reckoning before we can draw any conclusions from the flux of energy across the interface.

The equations of propagation are, for periodic motions in which $\frac{d}{dt}=\frac{\iota}{\tau}=-\iota\tau\frac{d^2}{dt^2}$, of the type

$$\mu K'\frac{d^2a}{dt^2}=\frac{dQ}{dz}-\frac{dR}{dy}-\frac{d}{dt}\left(b_1\frac{dP}{dx}+b_2\frac{dP}{dy}+b_3\frac{dP}{dz}\right),$$

where K′ is the complex quantity $\frac{K}{4\pi}\frac{d}{dt}+\sigma$, and where, when the axis of x is normal to an interface, the quantities above mentioned are to be continuous across it. The vector (a, β, γ) is in the wave-front of the undulations for, the magnetic permeability being constant,

$$\frac{da}{dx}+\frac{d\beta}{dy}+\frac{d\gamma}{dz}=0\,;$$

and it is in the plane of polarisation.

These equations may also be variously expressed in terms of other vectors, *e.g.*, of (P, Q, R) which is in the plane of the wave-front and transverse to the plane of polarisation, or of

$$\left(P-b_3\frac{dQ}{dt}+b_2\frac{dR}{dt},\ \ldots,\ \ldots\right).$$

The magnetic rotation is here to be explained by the single real vector coefficient (b_1, b_2, b_3); and the same value of this coefficient is in fact found to give a fairly good account of the various circumstances attending the rotation of the plane of polarisation in magnetic reflexion by iron and nickel, while it is also of the same order of magnitude as would correspond to Kundt's measures of the rotation produced by transmission through a thin film of iron.

14. A theory published a few months before by Goldhammer[1] goes, on the other hand, on the assumption that the effect of the magnetic field

[1] D. A. Goldhammer, 'Das Kerr'sche . . . Phänomen,' *Wied. Ann.*, xlvi. 1892, p. 71.

is to produce a temporary structural change in the medium. In the ordinary case of an isotropic medium

$$(u, v, w) = \left(\frac{K}{4\pi}\frac{d}{dt} + \sigma\right)(P, Q, R);$$

so that in periodic motion for which $\frac{d}{dt} = \frac{\iota}{\tau}$ we have

$$\frac{d}{dt}(P, Q, R) = \left(\frac{K}{4\pi} + \iota\sigma\tau\right)^{-1} (u, v, w) = \frac{4\pi}{K'}(u, v, w), \text{ say,}$$

in which the complex part of the coefficient, involving σ, represents the effect of conductivity. This is now replaced by a wider relation: in the general crystalline medium he proposes the form

$$\frac{dP}{dt} = \frac{4\pi}{K'_1} u + \lambda_3 v - \lambda_2 w + \mu_x \frac{du}{dt} + \mu_3 \frac{dv}{dt} - \mu_2 \frac{dw}{dt}$$

$$\frac{dQ}{dt} = \frac{4\pi}{K'_2} v + \lambda_1 w - \lambda_3 u + \mu_y \frac{dv}{dt} + \mu_1 \frac{dw}{dt} - \mu_3 \frac{du}{dt}$$

$$\frac{dR}{dt} = \frac{4\pi}{K'_3} w + \lambda_2 u - \lambda_1 v + \mu_z \frac{dw}{dt} + \mu_2 \frac{du}{dt} - \mu_1 \frac{dv}{dt},$$

in which μ_1, μ_2, μ_3 are assumed to be complex.

When the period $\tau/2\pi$ is very great the last terms, involving $\frac{d}{dt}(u, v, w)$, exert no appreciable effect, and so may be left out of account: the vector coefficient $(\lambda_1, \lambda_2, \lambda_3)$ which is left is the representative of the Hall effect. When the period $\tau/2\pi$ is very small, as in the case of light-waves, the rotational coefficient (μ_1, μ_2, μ_3) is preponderant, and the other one $(\lambda_1, \lambda_2, \lambda_3)$ may be neglected. We may also leave out of account the slight double refraction represented by the coefficients μ_x, μ_y, μ_z, as these are in nowise rotational. Thus, for an isotropic optical medium, the structural relation which connects electric force with electric current would reduce to the form

$$\frac{dP}{dt} = \frac{4\pi}{K'} u + \mu_3 \frac{dv}{dt} - \mu_2 \frac{dw}{dt}$$

$$\frac{dQ}{dt} = \frac{4\pi}{K'} v + \mu_1 \frac{dw}{dt} - \mu_3 \frac{du}{dt}$$

$$\frac{dR}{dt} = \frac{4\pi}{K'} w + \mu_2 \frac{du}{dt} - \mu_1 \frac{dv}{dt};$$

in which Goldhammer takes (μ_1, μ_2, μ_3) to be complex (unless the medium is transparent) and proportional to the intensity of the imposed magnetic field. This structural relation between magnetic induction and magnetic force is supposed to remain unmodifiable in form by magnetic or other disturbance. But it is not easy to understand the manner in which the relation is introduced into the equations of electro-dynamics, and the analysis to be given presently leads to a different result. The bodily equations are expressed in terms of Maxwell's vector-potential; they are the same in form as Drude's equations expressed in terms of magnetic force; and the boundary conditions assumed are continuity of the vector-potential

and its first differential coefficients, and continuity of the electrostatic potential.

15. The equations of Drude may be subjected to an important transformation which will bring them into line with another class of electrical theories. If in them we write

$$P' = P + b_3 \frac{dQ}{dt} - b_2 \frac{dR}{dt},$$

$$Q' = Q + b_1 \frac{dR}{dt} - b_3 \frac{dP}{dt},$$

$$R' = R + b_2 \frac{dP}{dt} - b_1 \frac{dQ}{dt},$$

and take (P', Q', R') as the electric force instead of (P, Q, R), we may preserve unaltered both of the fundamental circuital relations. The first one is clearly preserved; and so will be the second one if the relation between electric current and electric force is taken to be that derived by substitution from

$$(u, v, w) = \left(\frac{K}{4\pi}\frac{d}{dt} + \sigma\right)(P, Q, R).$$

This leads to a relation of type

$$P' = \left(\frac{K}{4\pi}\frac{d}{dt} + \sigma\right)^{-1}\left(u + b_3 \frac{dv}{dt} - b_2 \frac{dw}{dt}\right),$$

which differs from the structural relation assumed by Goldhammer, but is of the same class. When this transformation is made, Drude's boundary conditions become simply the ordinary ones which express that the tangential components of the electric force and the magnetic force are continuous in crossing the interface; the difficulty as to discontinuity in the tangential electric force does not now occur.

The special type of this relation which is assumed by Goldhammer is

$$\frac{dP}{dt} = \left(\frac{K}{4\pi}\frac{d}{dt} + \sigma\right)^{-1} u + \mu_3 \frac{dv}{dt} - \mu_2 \frac{dw}{dt},$$

in which he asserts that μ_1, μ_2, μ_3 are each, owing in some way to their origin, of the form $\frac{K'}{4\pi}\frac{d}{dt} + \sigma'$, so that they are complex constants of which the real and imaginary parts are, for the case of light-waves, of the same order of magnitude. He had previously rejected the coefficients $(\lambda_1, \lambda_2, \lambda_3)$ of the Hall effect as being for light-waves negligible in comparison with those retained, although the purely imaginary part of a coefficient of type μ must have the same character as they have, irrespective of magnitude. It is, perhaps, difficult to see any reason which would give probability to this assumption that the coefficients of type μ are complex quantities whose real and imaginary parts come to be precisely of the same order of magnitude.

16. A general formal development of the equations of the electromagnetic theory, which is necessarily wide enough to take account of all possible secondary phenomena, such as dispersion and circular polarisa-

tion, has been given in 1883 by Prof. Willard Gibbs,[1] under the title of 'An Investigation of the Velocity of Plane Waves of Light, in which they are regarded as consisting of solenoidal electrical fluxes in an indefinitely extended medium of uniform and very fine-grained structure.'

The principle on which his investigation is based is the very general idea that the regular simple harmonic light-waves traversing the medium excite secondary vibrations in its molecular electrical structure, which is supposed very fine compared with the length of a wave. When there is absorption the phases of these excited vibrations will differ from that of the exciting wave; but even in this most general case the simple harmonic electric flux with which we are alone concerned is at each point completely specified by six quantities, the three components of the flux itself, and the three components of its rate of change with the time. In the same way, the electric force may be similarly specified by six coordinates. Now the electric elasticity of the medium, as regards its power of transmitting waves, is specified by the relation connecting average force and average flux, this average referring to a region large compared with molecular structures, but small compared with a wave-length. The most general relation of this kind that can result from the elimination of the molecular vibrations must be of the form of six linear equations connecting the quantities specifying the flux with the quantities specifying the force, the coefficients being functions of the wave-length. If E denote the force and U the displacement, 'we may therefore write in vector notation

$$[\mathrm{E}]_{Ave}=\Phi[\mathrm{U}]_{Ave}+\Psi[\dot{\mathrm{U}}]_{Ave}$$

where Φ and Ψ denote linear functions.

'The optical properties of the media are determined by the forms of these functions. But all forms of linear functions would not be consistent with the principle of the conservation of energy.

'In media which are more or less opaque, and which, therefore, absorb energy, Ψ must be of such a form that the function always makes an acute angle (or none) with the independent variable. In perfectly transparent media Ψ must vanish, unless the function is at right angles to the independent variable. So far as is known, the last occurs only when the medium is subject to magnetic influence. In perfectly transparent media the principle of the conservation ef energy requires that Φ should be self-conjugate, *i.e.*, that for three directions at right angles to one another the function and independent variable should coincide in direction.

'In all isotropic media not subject to magnetic influence it is probable that Φ and Ψ reduce to numerical coefficients, as is certainly the case with Φ for transparent isotropic media.' [2]

For the further examination of the content of this relation connecting the two electric vectors we may express it in the symbolical form

$$[\text{flux}]=[p]\,[\text{force}]+\left[q\frac{d}{dt}\right][\text{force}]$$

[1] J. Willard Gibbs, 'On the General Equations of Monochromatic Light in Media of every Degree of Transparency,' *American Journal of Science*, February, 1883.

[2] J. Willard Gibbs, *loc. cit.*, p. 133; J. Larmor, *Proc. Lond. Math. Soc.*, xxiv. 1893, where, however, some of the statements need correction.

where $[p]$ and $\left[q\frac{d}{dt}\right]$ represent vectorial coefficients. For the simple harmonic oscillations of period τ that are here contemplated

$$\frac{d}{dt}=\frac{2\pi}{\tau}\iota,\ \frac{d^2}{dt^2}=-\left(\frac{2\pi}{\tau}\right)^2;$$

so that for the very small periods of light-vibrations multiplication of a coefficient by d/dt increases its importance enormously. When the oscillations are very slow the coefficient $[p]$ has still in a magnetic field a rotational part which reveals itself as the Hall effect; the presence of a coefficient $\left[q\frac{d}{dt}\right]$ could hardly be detected. On the other hand, with greater rapidity of vibrations, the importance of the rotational part in $\left[q\frac{d}{dt}\right]$ increases steadily, and finally absolutely overshadows any possible effect of the $[p]$ terms, unless the latter should contain a part whose origin was of the form $\left[r\frac{d^2}{dt^2}\right]$. If that were so, at a still higher rapidity of vibrations the $[p]$ terms would again become the important ones: but the wave-lengths would then be too small for such vibrations to have any physical reality.

17. The question occurs whether to secure complete generality a corresponding rotational quality should be imparted to the linear relation connecting the magnetic flux (*i.e.*, magnetic induction) with the magnetic force. It is, however, usual to assume, on various grounds, that the vibrations of light are too rapid to allow of their being accompanied by an oscillating magnetisation of the material medium. The phenomena of magnetisation of iron leave possibly no room for doubt that the magnetic movement is an affair of loosely associated groups of molecules, not of individual molecules themselves, the free periods corresponding to these groups being much too slow to follow the light-vibrations. These groups are broken up at the temperature of recalescence without the occurrence of any very striking effect: nor is there any striking difference in kind between the behaviour of iron to light and the behaviour of non-magnetic metals.

The effect of strong magnetisation on light-waves would be on this view a secondary effect due to a change of structure of the medium. Soon after the experimental discovery of the Hall effect, and the attention which was concentrated on it owing chiefly to the influence of Lord Kelvin, it was pointed out by J. Hopkinson that the existence of an effect of that character had been anticipated by Maxwell in his 'Treatise,' vol. i. § 303, where in discussing the possibility of the occurrence of a rotational term in the equations expressing the general form of Ohm's law of conduction, he remarks that such a coefficient 'we have reason to believe does not exist in any known substance. It should be found if anywhere in magnets, which have a polarisation in one direction, probably due to a rotational phenomenon in the substance.' The theory of such rotatory coefficients had also been worked out long before by Lord Kelvin,[1] in a thermo-electric connexion.

18. It seems worth while to examine how much in the way of magnetic

[1] *Cf.* Lord Kelvin (Sir W. Thomson), *Collected Papers*, vol. ii.

rotation can be got out of this relation by assuming the functions Φ and Ψ to have rotational quality; though Gibbs himself later on in his memoir qualifies its use by a statement that 'the equation would not hold in case of molecular vibrations excited by magnetic force. Such vibrations would constitute an oscillating magnetisation of the medium, which has already been excluded from the discussion.'

If the rotational quality is simply due to a magnetic field, we may take for brevity the direction of its lines of force to be along the axes of z, and the equations will be

$$u=\epsilon P-\upsilon Q$$
$$v=\epsilon Q+\upsilon P$$
$$w=\epsilon R$$

where $\epsilon=\frac{K}{4\pi}\frac{d}{dt}+\sigma$, and υ is of the form $\lambda\frac{d}{dt}+\nu$. The circuital relations of types

$$4\pi u=\frac{d\gamma}{dy}-\frac{d\beta}{dz},\quad -\frac{d\alpha}{dt}=\frac{dR}{dy}-\frac{dQ}{dz}$$

lead to

$$\nabla^2 P-\frac{d}{dx}\left(\frac{dP}{dx}+\frac{dQ}{dy}+\frac{dR}{dz}\right)=4\pi\frac{du}{dt}=4\pi\epsilon\frac{dP}{dt}-4\pi\upsilon\frac{dQ}{dt}.$$

Thus the rotational operator, instead of being of Maxwell's type $\frac{d^3}{dx^2dt}$ comes out of type $\left(\lambda\frac{d}{dt}+\nu\right)\frac{d}{dt}$.

Though a rotational term of this latter type, entering into the relation between current and force, and conjoined with the ordinary equations of electro-dynamics, leads, as we have just seen, to precisely the same scheme as Drude's to explain magnetic reflexion of waves of any single period; yet in order to take into account Verdet's laws of magnetic dispersion (in transparent media) the coefficients λ and ν have to be taken functions of the wave-lengths, whereas the coefficients in Drude's form of theory remain constant for all wave-lengths. The relation of Gibbs is competent to give an account of the laws of reflexion and of crystalline propagation for any one wave-length, by altering so to speak the electric inertia of the medium; and it fails for dispersion simply because the only method it possesses of rendering an account of dispersion is by accepting the observed facts, and making the coefficients functions of the wave-length. Thus we ought not to allow its failure to agree with magnetic dispersion to tell too much against the mode of explaining magnetic reflexion now under discussion. Yet the fact remains that the scheme embodied in Drude's equations has an advantage in comprehending a wider group of phenomena, and to that extent corresponds more fundamentally with the mechanism of the action; while on the other hand it exhibits, especially with regard to the boundary conditions, a more empirical character.

19. These equations we have named after Drude because his memoir contains by far the most detailed comparison with observation that has yet been made. The same equations, however, had been used by a number of other writers. For transparent media they had been obtained by Rowland [1] as equations of propagation, and they had been used by Fitz-

[1] H. A. Rowland, *Phil. Mag.*, 1881.

Gerald and by Basset[1] to calculate the circumstances of magnetic reflexion, without, however, entering into the case of metallic media. While recently J. J. Thomson[2] has employed them in an independent discussion of the laws of magnetic reflexion, which corroborates the main conclusions of Drude without going so much into detail. In dielectric media Rowland and Basset proceed simply by assuming rotational terms in the expression for the electric force on the analogy of the Hall effect in metals; and FitzGerald, as we have seen, deduces his equations from a new term in the energy which represents the linking on of the magnetic system. It is shown by J. J. Thomson, in his discussion of Kerr's results on reflexion, that in metals as well as dielectrics it is the time-rate of change of the induction or electric displacement, and not the total electric current, that combines with the magnetic field in the formation of this new term.

The boundary conditions are determined by FitzGerald and Basset from the hypotheses that the tangential magnetic force shall be continuous, and there shall be no concentration of energy, or *quasi*-Peltier effect, at the interface, subject however in the case of the latter to the same objection as has been applied above to Drude's use of this principle; while J. J. Thomson arrives at the same boundary conditions by postulating that the part of the electric force which is derived from the system itself must be continuous tangentially, whatever may happen to the part imposed from without.

20. There are thus two ways in which the magnetic field may affect the phenomena of light-propagation. The imposed magnetisation is an independent kinetic system of a vortical character which is linked on to the vibrational system which transmits the light-waves; the kinetic reaction between the two systems will add on new terms to the electric force: these terms are naturally continuous so long as the medium is continuous, but owing to their foreign origin they need not be continuous at an interface where the magnetised medium suddenly changes. At such an interface the other part of the electric force, which is derived from the vibrating system itself, has been assumed to be continuous in the ordinary manner, viz., its tangential components continuous; the total induction through the interface must of course always maintain continuity. This seems to be the type of theory developed by Maxwell in his hypothesis of molecular vortices ('Treatise,' § 822), and the conditions to which it leads have been applied to magnetic reflexion by the majority of writers on the subject, including Basset, Drude, J. J. Thomson. But against this procedure there stands the pure assumption as regards discontinuity of electric force at an interface. The correct boundary conditions would be derived from the modification of FitzGerald's procedure, which has been explained above.

The other point of view is the purely formal one contemplated by Lord Kelvin and Maxwell in their discussions of possible rotational coefficients introduced into the properties of the medium by magnetisation. The magnetisation is supposed to slightly alter the structure of the medium which conveys the light-vibrations, but not to exert a direct dynamical effect on these vibrations.

It would appear from the analysis of Drude, and more particularly

[1] A. B. Basset, *Phil. Trans.*, 1891.

[2] J. J. Thomson, 'Recent Researches . . .,' § 408, *seq*

of J. J. Thomson,[1] that there is some ground for assuming the correctness of the equations to which the former method leads; and those equations may be expressed in the terms of the second method somewhat as follows. The electric current is in a dielectric the rate of change of the electric displacement, which is of an elastic character; in a conducting medium part of the current is due to the continual damping of electric displacement in frictional modes: it may thus fairly be argued that the fundamental relation is primarily not between current and electric force, but between current and displacement, while the current is indirectly expressed in terms of electric force through the elastic relation between displacement and force. The equations would then run as follows, (ξ, η, ζ) being the electric displacement:

$$(u, v, w)=\left(\frac{d}{dt}+\frac{4\pi\sigma}{\mathrm{K}}\right)(\xi, \eta, \zeta),$$

where

$$\xi=\mathrm{P}-b_3\mathrm{Q}+b_2\mathrm{R};$$
$$\eta=\mathrm{Q}-b_1\mathrm{R}+b_3\mathrm{P};$$
$$\zeta=\mathrm{R}-b_2\mathrm{P}+b_1\mathrm{Q}.$$

This would make the relation between electric displacement and electric force of a rotational character, owing to the magnetisation. If the medium were not magnetised, Lord Kelvin's argument might be employed for the negation of such a rotational character, on the ground that a sphere rotating in an electric field would generate a perpetual motion; but as it is the rotation in the magnetic field would generate other electric forces. The frictional breaking down of displacement, viz., conduction, is known to assume a slightly rotational character, as manifested in the Hall effect.

Part II.—Correlation of General Optical Theories.

MacCullagh's Dynamical Theory of Light.

21. It has been remarked in this discussion of magneto-optic phenomena that a perfectly straightforward mechanical theory of magneto-optic reflexion would be obtained by adding on a uniaxial gyratory part to the energy-function of Lord Kelvin's labile æther.[2] The development of such a theory as this, after the manner already indicated, from the single basis of the principle of Least Action, would compare very favourably, by the absence of subsequent adjustment and assumption, with any of the foregoing explanations.

It has possibly been observed that the energy-function of FitzGerald's electro-dynamic analysis considered above is identical except as to surface terms with the energy-function of the labile æther theory, when (ξ, η, ζ) is taken to denote actual displacement of the medium. The difference that, for plane-polarised light, (ξ, η, ζ) is in the former case in the plane of polarisation, while in the latter case it is at right angles to that plane, is due, as we shall see, not to the fact that in the electric medium the compression $\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}$ is taken to be absolutely null, while in the labile æther the pressure is taken to be absolutely null or the medium is

[1] J. J. Thomson, 'Recent Advances in Electricity and Magnetism,' 1893, § 412.

[2] Lord Kelvin (Sir W. Thomson), 'On the Reflexion and Refraction of Light,' *Phil. Mag.*, 1888.

supposed devoid of consistence to compression, but it is the result of the neglected surface-terms on the energy-function. The correlation between an electric theory and a mechanical theory which follows from this comparison has already been alluded to by Willard Gibbs.[1] It will be found below that there is a similar correlation between two mechanical theories.

The vector (ξ, η, ζ) of FitzGerald's equations is, as he points out, exactly the displacement in MacCullagh's[2] *quasi*-mechanical theory of optical phenomena; and his analysis is for non-rotational media very much a translation of MacCullagh's work into electric terminology. The method followed in MacCullagh's extremely powerful investigation, which was independent of and nearly contemporary with those of Green,[3] and, I think, of at least equal importance, was to discover some form of the energy-function of the optical medium which shall lead by pure dynamical analysis in Lagrange's manner, without further hypothesis, to the various optical laws of Fresnel. In this he was completely successful, though Stokes[4] gives reason to doubt whether he has obtained the most general solution of his problem. His optical work has, however, to a great extent failed to receive due recognition from various causes; in particular the objection has been emphasised by Stokes (*loc. cit.*), and generally accepted, that the vector (ξ, η, ζ) which represents the light-disturbance in his analysis could not possibly be the displacement in a medium which transmits vibrations by elasticity in the manner of an ordinary elastic solid. 'Indeed MacCullagh himself expressly disclaimed to have given a mechanical theory of double refraction. (It would seem, however, that he rather felt the want of a mechanical theory, from which to deduce the form of the function Q or V, than doubted the correctness of that form itself.) His methods have been characterised as a sort of mathematical induction, and led him to the discovery of the mathematical laws of certain highly important optical phenomena. The discovery of such laws can hardly fail to be a great assistance towards the future establishment of a complete dynamical theory.'[5]

Since the date of these remarks the mechanical theory sought for has, I think, been supplied by Lord Kelvin's notion[6] of a medium dominated by some form of molecular angular momentum such as may be typified by spinning gyrostats imbedded in it. The gyrostatic part of the energy of strain of such a medium can be a quadratic function of its elementary twists or rotations, precisely after MacCullagh's form. The conjugate tangential tractions on the faces of a rectangular element of volume, instead of being equal and of the same sign as in the elasticity of solid bodies, are equal and of opposite sign,[7] just as Stokes pointed

[1] J. Willard Gibbs, 'A Comparison . . . ,' *Phil. Mag.*, 1889.

[2] James MacCullagh, 'An Essay towards a Dynamical Theory of Crystalline Reflexion and Refraction,' *Trans. R.I.A.*, December, 1839.

[3] George Green, 'On the Laws of the Reflexion and Refraction of Light at the Common Surface of two Non-crystallised Media,' *Cambridge Phil. Trans.*, December, 1837, with Supplement, May, 1839; George Green, 'On the Propagation of Light in Crystallised Media,' *Cambridge Phil. Trans.*, May, 1839.

[4] Sir G. G. Stokes, 'Report on Double Refraction,' *Brit. Assoc.*, 1862, p. 227.

[5] Sir G. G. Stokes, *loc. cit.*, p. 279.

[6] Lord Kelvin, *Comptes Rendus*, Sept., 1889; *Collected Papers*, vol. iii. 1890, p. 467.

[7] *Cf.* J. Larmor, 'On the Equations of Propagation of Disturbances in gyrostatically-loaded Media,' *Proc. Lond. Math. Soc.*, xxiii. 1891. The medium considered

out they would be on MacCullagh's theory. Consequently a framework free of elasticity of its own, and carrying a system of such gyrostatic cells, would be a mechanical representation of an æther which corresponds with MacCullagh's expression for the energy-function, and so would afford an explanation of optical phenomena on the lines of his analysis. The axes of the gyrostats will, in crystalline media, be concentrated in certain directions; but in any one direction as many must point backwards as forwards. Any very slight violation of the latter condition will introduce into the medium directed rotational property with respect to the resultant axes of angular momentum; such we may imagine to be the effect of an imposed magnetic field. Non-directed rotational property will be a structural effect, due to mode of aggregation. If the light-disturbance is represented by the displacement of the medium, it will be in the plane of polarisation; while if it is represented by the rotation, it will be at right angles to that plane. According to this theory of light, the density of the æther will be the same in all media; but in different media the distribution of angular momentum will vary.

22. The bodily equations of MacCullagh, when formulated in connexion with the boundary conditions appropriate to the theory of the elasticity of solids, which it is, I think, fair to say that their author never intended, and with which, in fact, Stokes pointed out that his whole scheme is inconsistent, have been shown[1] by various writers to lead to a wholly untenable account of reflexion.

The investigation of MacCullagh himself, based purely on dynamical analysis, leads him to the boundary conditions which alone are consistent with his scheme, much in the manner of FitzGerald's correlative electrodynamic theory sketched above. These conditions are quite different from the ones appropriate for an elastic solid medium.

The energy of MacCullagh's medium depends only on rotation, and not sensibly on compression. The compressional term can in general be absent only because either (i) there is no resistance offered to pressure, so that no work is done by it, or (ii) the medium is incompressible so that pressure *can* do no work. The tangential tractions on either side of an interface are expressed in terms of rotation, not of distortion as in the elastic solid theory.

The surface conditions are, however, theoretically too numerous, as MacCullagh knew but did not suffer from in the problem of crystalline reflexion, and as FitzGerald found irremediably in the magneto-optic problem. The way to remove this difficulty is to recognise, according to which of the above views we adopt, either (i) a local play of compression close to the interface which is not propagated away from it, which involves no sensible energy, but which renders it unnecessary to suppose the displacement normal to the interface to be continuous, or (ii) a play of pressure which is propagated from the interface with infinite velocity (*i.e.*, attains instantly an equilibrium distribution

in this paper is dominated by simple rotators imbedded in its structure, and the forcive is proportional to angular velocity. Lord Kelvin's new rotational medium is dominated by complex gyrostatic cells, containing arrangements of Foucault gyrostats, of which only the outer cases are firmly imbedded in the medium; and the forcive is proportional to the angular displacement.

[1] *Cf.* Lord Rayleigh, 'On the Reflexion of Light from Transparent Matter,' *Phil. Mag.*, 1871.

throughout the medium), and which therefore necessitates the modification of the equations of propagation as FitzGerald's equations are modified (*supra*, § 11), λ in that analysis being clearly a hydrostatic pressure when (ξ, η, ζ) represents linear displacement of the medium.

Any actual refracting system is of finite extent, so that the equilibrium state contemplated by (ii) is easily established throughout it: it is only for the simplification of analysis that it is customary to take the interface to be an unlimited plane.

The discussion of crystalline reflexion which is given by MacCullagh takes no account of this pressure λ, but makes an argument in favour of his theory out of the remarkable fact that although there are too many surface conditions compared with the number of variables, yet in no case is the introduction of such a pressure required by the analysis or the optical phenomena, provided the densities of both media are assumed to be the same; while FitzGerald's further application to magneto-optic reflexion simply leaves the continuity normal to the interface unsatisfied, and so far tacitly adopts the first of the above alternatives, that the medium, considered as a mechanical one, offers no resistance to compression—a hypothesis which turns out to be untenable.

23. If these considerations are sound, we have the following conclusions.

The phenomena of light are explained on MacCullagh's mathematical equations by a theory of pure rotational elasticity, without any accompaniment of the character of the elasticity due to change of volume or change of shape of an ordinary solid body; for linear vibrations the direction of the displacement of the medium is in the plane of polarisation of the light, while the axis of its rotation is at right angles to that plane. There is, however, no occasion to take the medium devoid of resistance to compression: it may transmit longitudinal waves with finite velocity, and still no such wave will be produced by the refraction of a transverse wave.

The electric theory of light is formally the same as MacCullagh's theory, magnetic force corresponding to velocity, provided his medium is taken to be incompressible.

The labile æther theory of Lord Kelvin is one that contemplates elastic quality depending on compression and distortion, *i.e.*, the ordinary elasticity of solid bodies, but the resistance of the medium to laminar compression is taken to be infinitesimal.

The difference between MacCullagh's theory and the electric theory does not, as has been just remarked, affect the problem of propagation in crystalline media, nor does it enter into the question of reflexion at an interface between either isotropic or crystalline media, the boundary conditions being all satisfied without any condensational disturbance; it is not necessary to introduce either (i) interfacial compression or (ii) hydrostatic pressure, according to the two cases above, to preserve the continuity at the interface. But we have already seen that the difference between these hypotheses makes itself felt in the problem of magneto-optic reflexion.

The labile æther theory stands, according to the remark of Willard Gibbs, already quoted, in a relation of precise duality to the electric theory, and therefore also to the other limiting interpretation of MacCullagh's theory, which postulates absence of volume elasticity; the linear displacement in the labile æther corresponds to the rotation in the

rotational æther. And here there is a point which demands explanation. The energy-function is the same in both the labile æther and this rotational æther; but the boundary conditions are different, being in the one case those of the elasticity of solids and in the other those of pure rotational elasticity. Yet, in the treatment of the subject proposed here, emphasis is laid, after MacCullagh, on the fact that the energy-function implicitly involves in itself the boundary conditions. This difficulty is elucidated by observing that the expression

$$\frac{1}{2}\int \mathrm{B}\left\{\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right)^2+\left(\frac{d\xi}{dz}-\frac{d\zeta}{dx}\right)^2+\left(\frac{d\eta}{dx}-\frac{d\xi}{dy}\right)^2\right\}d\tau,$$

given by Lord Kelvin[1] for the potential energy of the labile æther does not represent the localisation of the energy, considered as that of an elastic solid. It is in fact derived from the appropriate expression for an elastic solid

$$\frac{1}{2}\int \mathrm{B}\Big[\left(\frac{d\zeta}{dy}+\frac{d\eta}{dz}\right)^2+\left(\frac{d\xi}{dz}+\frac{d\zeta}{dx}\right)^2+\left(\frac{d\eta}{dx}+\frac{d\xi}{dy}\right)^2$$
$$-4\mathrm{B}\left(\frac{d\eta}{dy}\frac{d\zeta}{dz}+\frac{d\zeta}{dz}\frac{d\xi}{dx}+\frac{d\xi}{dx}\frac{d\eta}{dy}\right)\Big]d\tau$$

by integration of the second term by parts; and at an interface between different media, a surface term which will be found to be the difference for the two media of the values of the expression

$$\int \mathrm{B}\left\{l\left(\frac{d\xi\eta}{dy}-\frac{d\xi\zeta}{dz}\right)+m\left(\frac{d\eta\zeta}{dz}-\frac{d\eta\xi}{dx}\right)+n\left(\frac{d\zeta\xi}{dx}-\frac{d\zeta\eta}{dy}\right)\right\}d\mathrm{S}$$

is thus thrown away. Now a superficial distribution of energy is represented mechanically by a surface-tension of equal intensity; so that a surface-tension of this amount, varying from point to point, assists in keeping up the equilibrium of the interfacial layer, in addition to the surface forces indicated by MacCullagh's analysis.

Elucidation of a General Dynamical Principle.

24. A cardinal point in this correlation of different theories is the insistence on the validity of the proper application of MacCullagh's doctrine that the energy-function of a medium, provided it is correctly localised, contains implicitly in it the aggregate of the boundary conditions at an interface between two different media; and that notwithstanding any apparent discrepancy in continuity that may still be outstanding after the conditions so obtained have been applied to the problem. The same principle had previously been formulated by Green,[2] in similar terms; 'one of the advantages of this method, of great importance, is, that we are necessarily led by the mere process of the calculation, and with little care on our part, to all the equations and conditions which are *requisite* and *sufficient* for the complete solution of any problem to which it may be applied.' On the practical application of this procedure some fresh

[1] Lord Kelvin (Sir W. Thomson), *Phil. Mag.*, 1888.

[2] George Green, 'On the Laws of the Reflexion and Refraction of Light,' *Trans. Camb. Phil. Soc.*, December 11, 1837; *Math. Papers*, p. 246.

light may be thrown by the consideration of a quite similar difficulty in the dynamics of actual elastic systems, which has recently occupied the attention of several mathematicians. The vibrations of a curved elastic plate, in fact of a bell supposed of small thickness, have been worked out by Lord Rayleigh,[1] simply from the energy-function of the plate. The plate being thin, it can easily be deformed by bending; on the other hand to stretch it sensibly would be very difficult. For this reason the energy-function is formed by Lord Rayleigh on the assumption that the plate is perfectly inextensible, so that terms depending on extension do not occur in its expression. Some years subsequently it was pointed out by Love [2] that this treatment does not allow of all the elastic conditions at the boundary of the plate being satisfied. Now on the principles here expounded the adjustment of these terminal conditions would be made by tensions in the plate, which, owing to the very rapid velocity of propagation of extensional disturbances, practically obey at each instant an equilibrium theory of their own, and at the same time involve the play of only a negligible amount of energy owing to the magnitude of their elastic modulus. If the plate were quite inextensible these tensions would be absolutely in equilibrium at each instant, and the energy-changes involved in them would be null. And this view is, I believe, in agreement with the mode of explanation now generally accepted for that problem.[3] The solution of the problem of vibration of a bell may thus be derived, as regards all things essential, from the energy-function of the bending alone, combined explicitly or implicitly with the geometrical condition of absence of extension.

Critique of Kirchhoff's Theory.

25. The principle implied in MacCullagh's analysis is claimed to be identical, in its results if not in theory, with a hypothesis adopted by Kirchhoff in his discussion of crystalline reflexion,[4] which is commonly quoted by German authors under the title of Kirchhoff's principle. Its author employs it avowedly as a formal mathematical representation of assumptions made explicitly by F. Neumann, and tacitly he says by MacCullagh, in their theories, which it is the object of his memoir to reproduce and amplify. He attempts no dynamical justification of its use; on the other hand he rather formulates it as an additional hypothesis. At any rate it has been treated as a hypothesis by Kirchhoff's followers in Germany, while its validity is suspected by some other writers who have considered the subject. The explanation of Kirchhoff himself in the introductory paragraph of his memoir, in comparing Neumann's and MacCullagh's theories, is here reproduced in a free translation. 'Yet at the first glance the points of departure of the two theories would appear to be different, even diametrically opposed to each other. For Neumann starts from the view that the æther in respect of light-vibrations comports itself as an elastic solid, on whose elements no

[1] Lord Rayleigh, 'On the Infinitesimal Bending of Surfaces of Revolution,' *Proc. Lond. Math. Soc.*, xiii. 1882.

[2] A. E. H. Love, *Phil. Trans.*, 1888.

[3] *Cf.* A. E. H. Love, *Treatise on Elasticity*, vol. ii. 1893, § 349.

[4] G. Kirchhoff, 'Ueber die Reflexion und Brechung des Lichts an der Grenze krystallinischer Mittel,' *Abh. der Berl. Akad.*, 1876; *Gesammelte Abhandl.*, p. 352.

forces act except such as are called forth by their relative displacements; while MacCullagh takes for the potential of the forces in operation on the elements of the æther an expression which does not agree with the potential of the forces called into play by the relative displacements of the parts of an elastic solid. Thus in the theory of MacCullagh, if we are to treat the æther as an elastic solid, we must treat it as one which is acted on by forces in addition to those called into play by its elasticity. Yet of these other forces it may be proved from the energy-function adopted by MacCullagh that, taken throughout a portion of the æther in a homogeneous body, they reduce to tractions which operate on its surface. We can therefore assert, that the theory of MacCullagh rests on the hypothesis that on the elements of the æther no forces act except such as are derived from its elasticity; but on the surfaces which form the boundaries of heterogeneous media tractions are imposed which have some other origin. And such tractions must also be contemplated by Neumann's theory; their function is that we are by their aid empowered to leave the compressional wave out of consideration, just as happens in the former theory: they must exist, in order that compressional waves may not be set up in the reflexion and refraction of light-waves. The two theories compared can thus be seen to be in complete accord. I propose to myself to lay before the Academy a treatment of the question from the standpoint of these theories which, I think, is more general and more comprehensive than those that have been given hitherto.' These imposed interfacial forces are restricted merely to satisfy the condition that they shall do no work on any element during the actual displacements of the media; they are considered by Kirchhoff to be 'tractions from without (*fremden Druckkräfte*) which act on an element of the interface, tractions which, we are accustomed to assert, arise from the forces which the ponderable parts of the two media sustain from the æther.'[1] The forces contemplated by Kirchhoff's principle, in order to allow of the condition of incompressibility being satisfied, are thus only interfacial tractions, which form an equilibrating system in so far as they do no work in any displacement actually contemplated. According to the elucidation and extension of MacCullagh's principle which is here proposed, they should be taken to be a system of pressures distributed throughout the media, which do no work for the displacements actually contemplated, and which are in so far equilibrating. These pressures will be discontinuous at an interface; and will hence modify the boundary conditions in the same manner as Kirchhoff's extraneous forces.

26. In the account of Kirchhoff's principle given by Volkmann,[2] the view is propounded that such a principle is necessary because the equations of an elastic solid medium, with the addition of a pressure introduced in the manner indicated above (§ 11), will not lead to an account of reflexion which is in accordance with experiment. Quoting from Kirchhoff's lectures on Optics (p. 143), 'We have to recognise that the elasticity of the æther is different in the various transparent media, different in glass, for example, from what it is in empty space. We are not in a position to form for ourselves a clear representation as to how the alteration of the elasticity of the æther in glass is brought about; but

[1] G. Kirchhoff, *loc. cit.*; *Gesammelte Abhandl.*, p. 367.
[2] P. Volkmann, *Theorie des Lichtes*, 1891 § 76.

still we can say that it is a consequence of *forces* which the elements of the ponderable matter exert on the elements of the æther. As therefore such forces are present they must exert a *direct* influence on the motion of the elements of the æther at the boundary of the glass, though in the interior of the glass they have only an indirect influence in altering the elasticity of the æther. The relations of the direct action of these forces at the surface and in the interior are similar to those which hold with capillary forces, which also are only of influence at the surfaces of fluids, and are not felt in the interior.' This quotation has been given at length, as it puts the case precisely. The reply is that it is only a confession of total ignorance as to the distribution of the energy throughout the mass of the media which would permit us to prop up the boundary conditions by extraneous forces in this manner. In the theory of capillarity the surface-tractions are derived from the distribution of energy throughout the mass of the liquid; and if they could not be deduced rationally from some possible volume distribution of energy, it would have to be held that they were erroneous. So here, if Kirchhoff's extraneous surface-tractions cannot be deduced from some energy-function of the complex medium (æther and matter) which is the seat of the undulations, there is absolutely no basis left for them. It will not suffice to say that at the boundary there is interaction between the æther and the matter, and a gradual transition in density caused by the equilibration of such action: if the depth of this layer of transition is a small fraction of the wave-length, the introduction of the energy-function appropriate to it would have but a small influence on the variation of the total energy, and so would not sensibly affect the results. In so far as the introduction of the pressure arising mathematically from the condition of incompressibility will not make an elastic theory work, that theory has simply not been sustained; in various theories above mentioned the introduction of the pressure is efficacious, and they are in so far verified and in a position to be further tested by application to more complicated phenomena.

Although it would seem that Kirchhoff's method cannot be maintained, yet, as he remarks, his formal equations come out the same as those of the rotational theory represented by MacCullagh's equations; so that his detailed development of the problem of crystalline reflexion will be in agreement with MacCullagh's, and holds good so far as it goes.

27. In the theory of Neumann, which contains one of the first attempts at a rational dynamical treatment of reflexion and refraction, he starts with equations for the strain of an elastic crystalline medium, of the imperfect type, however, which the then current elastic theory of Navier and Poisson supplied. By assumption of special relations between the constant coefficients of these equations, he obtained a form which led approximately to Fresnel's laws of double refraction.[1] He then applied this form to the problem of crystalline reflexion,[2] but found, I suppose, that the six conditions which he recognised as necessary to ensure continuity of displacement and stress at the interface could not all be satisfied. To satisfy them in a case of an ordinary compressible medium would require the introduction of a wave of longitudinal displacement in each medium, set up in the act of refraction; Neumann's

[1] F. E. Neumann, *Pogg. Ann.*, xxv.

[2] F. E. Neumann, *Abhandlungen der Berliner Akademie*, 1835. This memoir proceeds throughout on the method of rays, without explicit consideration of the elasticity of the medium.

medium being incompressible, he did not take account of such waves, and so was in difficulty with his boundary equations. He cut the knot by assuming that the displacement is continuous across the interface, in other words that there can be no rupture of material continuity; and by omitting altogether all conditions of continuity of stress, replacing them by the principle that there is no loss of energy in the act of refraction and reflexion. This, as Kirchhoff remarks, is equivalent to an admission that the equilibrium (or vibrational motion) of an indefinitely thin layer, including in it the interface, is maintained by the aid of forces introduced somehow from outside the vibrating system; but that, as the energy of the incident light is accounted for exactly by that of the reflected and refracted light, these forces must be subject to the condition that they do no work on any element of this surface layer in the displacements to which the medium is *actually* subjected during the motion. On this basis Neumann obtains Fresnel's equations of reflexion, by aid of the hypotheses that the displacement of a linear wave is in the plane of polarisation, and that media differ optically in elasticity but not in density.

As we have seen, Kirchhoff adopts and expounds the method initiated by Neumann for getting over the boundary difficulty. But his main argument is that if we do not assume surface forces from without we are helpless, that such forces exist, as is inferred from molecular theory, but that all we know about them is that in their play they cannot absorb any of the energy of the light. His method of procedure would therefore be to assume the most general possible type of such forces subject to this one condition, and then try by special assumption to adjust them to the final result he desires. There is clearly no dynamical validity in this, it is purely empirical; the surface forces may really be subject (as we shall see, are subject) to other unknown laws as well, which will not, with the assumed energy-function of the medium, allow of the desired solution. The process would then only prove that the assumed energy-function is untenable.

28. The correct method is the one indicated above. The energy of the medium is associated with the medium in bulk, is located in its elements of volume. In Gauss' theory of capillarity it is true that interfacial energy is contemplated, but that is only the actual excess or defect of the energy in the very thin layer of transition over what its amount would be if the transition was supposed sharp and the density of the energy in the elements of each medium near the surface were unaltered by the neighbourhood of the other medium. It is this portion of the energy that produces superficial effects such as surface-tension, though owing to the thinness of the interfacial layer it forms only a very minute fraction of the whole energy, the distribution of the other part being uniform. Now the propagation of vibrations across the interface is an affair of the redistribution of the energy of the medium *en masse*; if we make the ordinary optical hypothesis that the layer of transition is very thin compared with the length of a wave, we may be certain that there is no superficial term of sensible importance in the vibrational energy of the system. The only superficial forces which can come in are, then, those which enter logically in the dynamical analysis of the motion, on the basis of a volume distribution of energy in the medium, the determination of whose form is part of the problem. Until the possibilities of this statement of the problem are exhausted, it would appear to be gratuitous and unscientific to assume the existence of unknown surface-forces; and more-

over, as these forces could only arise from the existence of a finite layer of transition, so not only would their assumption be purely empirical, but the present method of investigation of the problem of reflexion would actually no longer apply: if there is to be a finite layer of transition, the postulation of material continuity of the media across it by means of a single set of surface conditions would be meaningless.

29. In the light of these remarks it will be of interest to follow somewhat in detail Kirchhoff's discussion of the general problem of crystalline reflexion and refraction, to find out how far his imposed surface forces satisfy the conditions that we here demand of them, namely, of being deducible from a bodily energy-function. Kirchhoff restricts himself to an elastic solid æther; three sets of waves will thus be possible with a given front; the restriction that the displacement for two of these waves shall be in the plane of the front confines the energy-function to Green's well-known form.[1]

He then neglects the first term involving the compression, in Green's formula, on the ground that in the transverse waves the density of the medium remains unaltered,[2] so that such a term can have no influence on the equations. If he had definitely omitted this term from the energy, the analysis, as carried out by him without an introduced pressure, would have shown that the function so modified belongs to a medium in which a compressional wave is propagated with null velocity, in fact a medium which (like Lord Kelvin's foam) opposes no resistance to *laminar* compression, though it does resist *uniform* compression with a finite volume-elasticity. Green was not able to do away in this manner with the terms producing a normal wave, because he thought his medium would be unstable; and possibly the same idea suggested Kirchhoff's cautious procedure.

This energy-function F, with the compression omitted, is easily expressed, in the notation of § 11, in the form

$$\mathrm{F}=\mathrm{U}-2a_{11}\frac{d(\eta,\zeta)}{d(y,z)}+\ldots+\ldots$$
$$-2a_{23}\left\{\frac{d(\xi,\eta)}{d(x,z)}+\frac{d(\xi,\zeta)}{d(x,y)}\right\}-\ldots-\ldots$$

where

$$2\mathrm{U}=a_{11}f^2+a_{22}g^2+a_{33}h^2+2a_{23}gh+2a_{31}hf+2a_{12}fg,$$

(f, g, h) being the curl of the displacement (ξ, η, ζ) of the medium. By integration by parts, all the terms of the volume integral $\int \mathrm{F}d\tau$ except U are clearly expressible as surface integrals; while U, the remaining volume distribution, is identical with the *complete* energy-function of MacCullagh's medium. The interfacial part of the energy F, when thus expressed, is (l, m, n), being direction cosines, the difference in value on the two sides of the interface of the expression

$$-2a_{11}\left(m\eta\frac{d\zeta}{dz}-n\zeta\frac{d\eta}{dy}\right)-2a_{22}\left(n\zeta\frac{d\xi}{dx}-l\xi\frac{d\zeta}{dz}\right)-2a_{33}\left(l\xi\frac{d\eta}{dy}-m\eta\frac{d\xi}{dx}\right)$$
$$-2\left(a_{23}\frac{d\xi}{dx}+a_{31}\frac{d\eta}{dy}+a_{12}\frac{d\zeta}{dz}\right)(l\xi+m\eta+n\zeta)$$
$$+2(a_{23}l\xi+a_{31}m\eta+a_{12}n\zeta)\left(\frac{d\xi}{dx}+\frac{d\eta}{dy}+\frac{d\zeta}{dz}\right).$$

[1] G. Green, *Cambridge Phil. Trans.*, 1839.
[2] As explicitly recognised by MacCullagh. See Sir G. G. Stokes' *Report.*

If we take for an instant the plane of (xy) to be the interface, so that $(l, m, n)=(0, 0, 1)$, this expression becomes

$$2\xi\left\{(a_{22}+a_{23}-a_{21})\frac{d\zeta}{dz}-(a_{33}+a_{32}-a_{31})\frac{d\eta}{dy}\right\}.$$

Now on any form of interpretation of MacCullagh's theory, no extraneous interfacial forces at all are required to satisfy the boundary conditions; if the present theory is to agree with it, we might expect that there will be required only interfacial forces such that their activity will for the actual motion just undo the variations of this surface-energy. But the boundary conditions of MacCullagh are (§ 9)

$$\xi, \eta, \zeta, \frac{dU}{dg} \text{ and } \frac{dU}{dh}$$

all continuous, where $\int U d\tau$ is the statical energy; and these do not suffice to make this surface-energy constant, *i.e.*, the time variations of the above expression continuous across the interface. As already remarked, the theories of Kirchhoff and MacCullagh are formally identical; therefore there must be some discrepancy here. It is in fact the circumstance that this surface-integral part of the energy has lost its correct location, and does not really belong to the place with which it is now analytically associated.

Again, Kirchhoff's actual procedure is to take the tractions (X, Y, Z) and (X′, Y′, Z′) on the two sides of the interface that are derived in Lagrange's manner from the energy-function, and to equate to nothing their activity

$$(X-X')\frac{d\xi}{dt}+(Y-Y')\frac{d\eta}{dt}+(Z-Z')\frac{d\zeta}{dt}.$$

If ξ, η, ζ are quite independent this will give three boundary conditions just as before, and will be no help. But in the motion to which he restricts himself, ξ, η, ζ are the displacements in a plane-wave, and so are functions of the same linear function of x, y, z and t; he finds that the introduction of this restriction reduces the conditions to two, and so allows further progress.

The reason which Kirchhoff assigns for the two theories of himself and MacCullagh being analytically in agreement is that they can only differ as to boundary conditions, that he gets to a definite theory by his principle of extraneous forces, and that MacCullagh's definite theory also satisfies this principle from the simple fact that there are no extraneous forces. But then the energy-functions are not the same in the two theories. The Fresnel laws of reflexion are obtained by Neumann really by the hypothesis that for rays, *i.e.*, for *simple wave-trains*, no loss of energy occurs in the reflexion. This is a much narrower principle than its generalisation by Kirchhoff; and, as we have seen, to make his generalisation work, the latter has to return practically to Neumann's form in which it is restricted to plane-waves.

These considerations are set forth as showing the artificial character of Kirchhoff's principle, and illustrating the various mistakes and misconceptions which may arise in connexion with a subtle point of analytical dynamics, of which the physical bearing has not, I think, been realised by many of the writers on this subject.

In contrast with these explanations, the real reason why the theories of MacCullagh and Kirchhoff agree in their results will now be stated. It is simply that, when ξ, η, ζ are functions of a linear function of x, y, z and t, and therefore are the displacements in a plane-wave of some form, the unmodified expression for Kirchhoff's energy-function F reduces to MacCullagh's energy-function U, the various Jacobian expressions $d(\eta, \zeta)/d(y, z)$, &c., contained in it being all null. For a wave with a spherical or other curved form of front, these terms would not thus disappear; and the boundary conditions could not, I think, be reduced to the proper number by Kirchhoff's process. The conclusion to be drawn from this would be as before mentioned, not that reflexion cannot be explained, but that Green's expression for the energy, as employed by Kirchhoff, is untenable.

We have seen that a labile æther gives results conjugate to, but not the same as, those of the rotational æther corresponding to MacCullagh's equations. It is also known that Neumann's simple theory which can be expressed by means of rays, without technical considerations of elasticity, leads to the same results as MacCullagh's; and we now see that Kirchhoff's method would lead to the same result. Now the elastic solid theory of Kirchhoff is in its elements just the same as the labile æther elastic solid theory; and yet Kirchhoff gets a different result out of it. This demonstrates still further the faultiness of his procedure: he is not entitled to throw away the Jacobian terms in the energy because they happen to be null for the plane-wave kind of motion which he assumes to be the only one to which the reflexion will give rise; though he happens to be led to the correct result by equilibrating them, as he can clearly do *for this particular case*, by extraneous surface tractions of null activity. Further, it thus appears that, according to the form he takes for his extraneous forces, he can arrive from the same *data* at *either* of two conjugate theories of reflexion.

Mechanical Illustrations of MacCullagh's Theory.

30. The conclusions here arrived at naturally tempt one to pursue the invention of mechanical illustrations of the æther. Lord Kelvin proposes to realise and illustrate his labile contractile æther by a homogeneous mass of foam free from air. Such a medium, when distorted, will have its equilibrium disturbed, and will tend to recover itself; when uniformly compressed it will exhibit volume-elasticity. But when it is compressed in one direction only in plane layers, there will be no tendency to recover: its Young's modulus will be null, and so there will exist a fixed ratio between its compressibility and its rigidity, an interesting result which it would be rather difficult to investigate directly. Longitudinal waves will thus not be propagated in the medium.

We have also two types of Lord Kelvin's gyrostatic æthers, one of them with pure rotational elasticity and no compressional or distortional elasticity, the other incompressible but with no distortional elasticity; either of them will represent MacCullagh's equations. A mechanical realisation of an æther of the second kind has been proposed by FitzGerald as consisting of a web of long vortex filaments, interlaced together in homogeneous frictionless incompressible liquid, with any desired isotropic or crystalline quality: but even if we could be assured that such a system could subsist, and not be at once hopelessly entangled and

destroyed owing to instability, as seems likely, its elasticity would appear at first sight to depend on angular velocity and not on angular displacement, so that it could not have the properties of MacCullagh's æther.[1] Lord Kelvin has recently occupied himself[2] with the dynamics of media composed of gyrostats mounted on framework having various degrees of mechanical freedom. It is possible to imagine frames devoid of distortional elasticity and either incompressible or devoid of compressional elasticity, one of the former class being simply composed of rectangular parallelepipedal webs hinged together, each web consisting of three systems of parallel rods freely jointed at their points of meeting.

But we ought not to lose sight of the fact that a gyrostatic æther will be effective, whatever be its modulus of compressibility, provided it has no purely distortional elasticity. Thus FitzGerald's fluid need not be incompressible; an oblique parallelepipedal frame on which to mount the gyrostats will do equally as well as a rectangular frame; and we may also have more complicated forms.[3]

The wide field of physical theory which is opened up by this remark that in a rotational æther, however heterogeneous it may be, compressional waves are propagated in perfect independence of rotational waves, must be reserved for future consideration. A generalisation of Maxwell's electrodynamic equations has been already proposed and discussed by von Helmholtz, which introduces the possibility of compressional disturbances; but that theory is on quite a different footing from the one here suggested, in that Helmholtz's compressional wave interacts with the rotational one, getting mixed up with it at each refraction into a different medium.

The only optical phenomena which the compression can affect, on MacCullagh's theory, appear to be magneto-optic reflexion and possibly other such secondary disturbances, depending on the introduction of terms of higher orders into the energy-function.

The Bibliography of Solution.—Report of the Committee, consisting of Professor W. A. TILDEN (*Chairman*), Dr. W. W. J. NICOL (*Secretary*), Professor H. McLEOD, Mr. S. U. PICKERING, Professor W. RAMSAY, *and* Professor SYDNEY YOUNG.

THE Committee regret that but little progress has been made with their work since the date of the last report. They hope, however, to complete the work this year, and arrange it in a form suitable for publication. They therefore desire reappointment without a grant.

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[1] See, however, Lord Kelvin (Sir W. Thomson), 'On the Propagation of Laminar Motion through a turbulently-moving inviscid Fluid,' *Phil. Mag.*, 1887.

[2] Lord Kelvin (Sir W. Thomson), *Collected Papers*, vol. iii. 1890, pp. 466–472.

[3] *Cf.* J. Larmor, 'On Possible Systems of Jointed Wickerwork, and their Degrees of Internal Freedom,' *Proc. Cambridge Phil. Soc.*, 1884.

The Action of Light upon Dyed Colours.—Report of Committee, consisting of Professor T. E. Thorpe (*Chairman*), Professor J. J. Hummel (*Secretary*), Dr. W. H. Perkin, Professor W. J. Russell, Captain Abney, Professor W. Stroud, *and* Professor R. Meldola. (*Drawn up by the Secretary.*)

The object of the Committee appointed to study this matter has been to determine by experiment the relative fastness to light of the colours dyed on textile fabrics with the various natural and artificial colouring matters.

For this purpose patterns of silk, wool, and cotton have been dyed with equal percentages (2 per cent.) of the various commercial artificial colouring matters. With the natural colouring matters the patterns were dyed to approximately the same depth of colour.

The patterns were exposed to light at Adel, a country district about five miles to the north of Leeds, in order to avoid the influence of town smoke, sulphurous acid, &c., the prevailing winds being westerly. The patterns were pinned on deal boards covered with white calico, fixed in a vertical position in glazed wooden cases, so arranged as to permit free circulation of the air and moisture after filtration through cotton wool to exclude dust, &c.

The exposing cases were set up in the grounds of Jas. A. Hirst, Esq., to whom the best thanks of the Committee are due for his kind permission to do so.

Each dyed pattern was divided into six pieces, one of which was protected from the action of light, while the others were exposed for different periods of time. The shortest period of exposure, or 'fading period,' was about three weeks (May 24 to June 14, 1892), and a record of the fading power of this period was kept by exposing along with the patterns a special series of 'standards' dyed with selected colouring matters. These standards were removed from the action of the light along with the first set of dyed patterns at the end of the first 'fading period' (May 24 to June 14, 1892). The faded standards were then at once replaced by a fresh unexposed series, and these were allowed to fade to the same extent as the first, when, a second period of exposure equal in fading power to the first having thus been marked off, a second set of the dyed patterns were removed from the action of light along with the second series of faded standards. The latter were again renewed as before to mark off the next 'fading period.' The fourth and fifth sets of dyed patterns were submitted to an exposure equivalent to two or three 'fading periods' in order that the fifth set might have an exposure of one year.

The above method was adopted in order to be able to expose dyed patterns to an equal amount of fading in different years, irrespective of the time of the year or the conditions of light, moisture, temperature, &c. It was rendered necessary indeed in consequence of the practical impossibility of exposing simultaneously a complete set of dyed colours.

During the year 1892–93 the red dyes on wool and silk have been exposed. For want of sufficient exposing space, however, the Congo colours and some others, as well as the reds dyed on cotton, had to be omitted. During 1893–94 the orange and yellow dyes are being exposed, and the remaining colours will be exposed in subsequent years

until all have been examined. There is no doubt but that the behaviour of dyed colours towards light and other agencies depends upon several factors, *e.g.*, the chemical constitution of the colouring matter itself, the kind of fibre to which it is applied, the method of application, &c. With so many variables a full and complete examination of the question of the fastness of dyes proves to be one of extreme complexity and difficulty. Even to determine effectually the nature of the relationship existing between the molecular constitution of colouring matters and their behaviour towards light seems to necessitate the employment of chemically pure dye-stuffs, and that the dyeing should be so arranged as to have an equal number of molecules of colouring matter on a given weight of textile material. Having regard, therefore, to the difficulties connected with the purification of such a large number of colouring matters as are now in use, their varying colouring power, the different degree to which they exhaust the dye-bath, &c., it seemed better, for the present at least, to confine our attention to a comparison of the relative fastness to light of the various distinct commercial colours, the results of which might form a basis for a further examination in the direction alluded to.

The dyed and faded patterns have been entered in pattern-card books in such a manner that they can be readily compared with each other.

The following tables give the general result of the exposure experiments made during the year 1892–93, the colours being divided, according to their behaviour towards light, into the following five classes: Very fugitive, fugitive, moderately fast, fast, very fast.

The initial numbers refer to the order of the patterns in the pattern books. The S. and J. numbers refer to Schultz and Julius' 'Tabellarische Uebersicht der künstlichen organischen Farbstoffen.'

Class I. Very Fugitive Colours. (Wool.)

The colours of this class have faded so rapidly that at the end of the first 'fading period' (May 24 to June 14, 1892) only a very faint colour remains, and at the end of the fifth period (one year) all traces of the original colour have disappeared, the woollen cloth being quite white or of a yellowish tint.

Triphenylmethan Colours. Phthaleïns.

Wool Book II.

Eosins. 1. Eosin A. Alkali salt of tetra-brom-fluoresceïn. S. and J. 319.

„ 2. Erythrosin G. Alkali salt of di-iodo-fluoresceïn. S. and J. 324.

„ 3. Methyl-eosin. Potassium salt of tetra-brom-fluoresceïn-methyl-ether. S. and J. 320.

„ 4. Erythrosin JN pure. Sodium salt of tetra-iodo-fluoresceïn.

„ 5. Eosin S. Potassium salt of tetra-brom-fluoresceïn-ethyl-ether. S. and J. 321.

„ 6. Eosin F. Same as 4.

„ 7. Phloxin P. Potassium salt of tetra-brom-di-chlor-fluoresceïn. S. and J. 325.

„ 8. Eosin BN. Potassium salt of di-brom-di-nitro-fluoresceïn. S. and J. 322.

„ 9. Erythrosin B. Sodium salt of tetra-brom-tetra-chlor-fluoresceïn. S. and J. 328.

„ 10. Cyanosin (spirit soluble). Potassium salt of tetra-brom-di-chlor-fluoresceïn-methyl-ether. S. and J. 326.

„ 11. Cyanosin B. Sodium salt of tetra-brom-tetra-chlor-fluoresceïn-ethyl-ether. S. and J. 329.

„ 12. Phloxin tetra (pure). Same as 9.

Wool Book II.

Eosins. 13. Rose Bengale NTO. Alkali salt of tetra-iodo-dichlor-fluoresceïn.

„ 14. Phloxin. Same as 9.

„ 15. Rose Bengale NT pure. Same as 13.

„ 16. Bengaline PH. Sodium salt of tetra-iodo-tetra-chlor-fluoresceïn.

„ 17. Bengal Red B. Potassium salt of tetra-iodo-tetra-chlor-fluoresceïn. S. and J. 330.

„ 18. Cyclamine. Eosin from thio-dichlor-fluoresceïn. S. and J. 334.

Azine Colours. Safranines, &c.

Basic Reds. 6. Safranine B extra. From 1 mol. *p*-phenylene-diamine and 2 mols. aniline. S. and J. 356.

„ 7. Safranine T extra. From 1 mol. *p*-toluylene-diamine, 1 mol. aniline, 1 mol. *o*-toluidine. S. and J. 358.

„ 8. Diamido-phenazin-nitrate. Tolu-safranine-nitrate.

„ 9. Neutral Red. From dimethyl-diamido-toluphenazine hydrochloride. S. and J. 353.

„ 11. Fuchsia. From 1 mol. dimethyl-*p*-phenylene-diamine and 2 mols. aniline. S. and J. 357.

Induline Colours. Rosindulines.

Wool Book I.

Acid Reds. 9. Rosinduline 2 G. Constitution not published.

„ 30. Rosinduline G. Constitution not published.

Azo Colours.

Acid Reds. 43. Roxamine. From azo deriv. of naphthionic acid and dioxynaphthalene (2·7).

NOTES.—Among the eosins, eosin BN is distinctly faster than the rest; cyanosin B fades as rapidly as the rest during the first 'fading period,' but the pale tint then left is remarkable for its fastness, since it remains almost unchanged even after a year's exposure.

The eosins, rosindulines, and roxamine do not alter in tint when fading, but the safranines leave, at the end of the first 'fading period,' a dull brownish-pink tint.

CLASS II. FUGITIVE COLOURS. (WOOL.)

The colours of this class show very marked fading at the end of the second 'fading period' (June 14 to July 21, 1892), and after a year's exposure they have entirely faded, or only a tint remains.

Triphenylmethan Colours. Rosanilines.

Wool Book II.

Basic Reds. 12. Fuchsin MN. Rosaniline hydrochloride.

„ 13. Para-rosaniline. Para-rosaniline (base).

„ 14. Rosaniline. Rosaniline (base).

„ 15. Acetic acid Rubin. Rosaniline acetate.

„ 16. Magenta. Rosaniline hydrochloride.

„ 17. New Magenta. Tri-methyl-*p*-rosaniline-hydrochloride.

Wool Book I.

Acid Reds. 99. Acid Magenta. Alkali salt of rosaniline-tri-sulphonic acid. S. and J. 279.

Phthaleïns.

Wool Book II.

Basic Reds. 1. Rhodamine. Phthaleïn of diethyl-*m*-amido-phenol (basic hydrochloride). S. and J. 331.

„ 2. Rhodamine B extra. As No. 1.

Wool Book II.
Basic Reds. 3. Rhodamine S. Succineïn of diethyl-*m*-amido-phenol-hydrochloride. S. and J. 333.
„ 4. Rhodamine S extra. Succineïn of di-methyl-*m*-amido-phenol-hydrochloride. S. and J. 332.

Diphenylmethan Colours.

„ 10. Pyronin G. Tetra-methyl-diamido-oxy-diphenyl-carbinol hydrochloride. S. and J. 261.
„ 5. Acridine Red 3 B. A yellow shade of pyronin.

Azine Colours. Safranines.

„ 18. Magdala Red. Diamido - naphthyl - naphthazonium chloride. S. and J.

Azo Colours.

Wool Book I.
Acid Reds. 12. Acid Ponceau. From β-naphthylamine-mono-sulphonic acid and β-naphthol. S. and J. 92.
„ 16. Double Brilliant Scarlet G. From β-naphthylamine-mono-sulphonic acid (Br.) and β-naphthol. S. and J. 94.
„ 50. Phenanthrene Red.
„ 54. Cresol Red. From amido-ortho-cresol-ethyl-ether and β-naphthol-di-sulphonic acid R. S. and J. 57.
„ 58. Milling Red G. Constitution not published.
„ 59. Clayton Cloth Red. From dehydro-thio-*p*-toluidine-sulphonic acid and β-naphthol. S. and J. 99.
„ 60. Cloth Red 3 G extra. From amido-azo-toluene and β-naphthylamine-mono-sulphonic acid Br. S. and J. 116.
„ 61. Caroubier.
„ 62. Fast Red A. From naphthionic acid and β-naphthol. S. and J. 84.
„ 68. Fast Red BT conc. From α-naphthylamine and β-naphthol-mono-sulphonic acid S. S. and J. 62.
„ 73. Cloth Red 3 B extra. From amido-azo-toluene and β-naphthylamine-mono-sulphonic acid S. S. and J. 115.
„ 76. Ponceau 2 S extra. From amido-azo-benzene and β-naphthol-di-sulphonic acid R. S. and J. 110.
„ 83. Naphthorubin. From α-naphthylamine and α-naphthol-di-sulphonic acid. S. and J. 63.
„ 84. Thiorubin. From dehydro-thio-*p*-toluidine and β-naphthol-di-sulphonic acid R. S. and J. 68.
„ 88. Orchil substitute N. From *p*-nitraniline and α-naphthylamine-di-sulphonic acid. S. and J. 39.
„ 89. Bordeaux BX. From amido-azo-xylene and β-naphthol-β-mono-sulphonic acid. S. and J. 117.
„ 90. Orchil substitute V. From *p*-nitraniline and naphthionic acid. S. and J. 36.
„ 92. Milling Red R. Constitution not published.
„ 94. Orchil substitute 3 VN. From *p*-nitraniline and α-naphthylamine-mono-sulphonic acid L. S. and J. 38.
„ 96. Fast Red B. From α-naphthylamine and β-naphthol-di-sulphonic acid R. S. and J. 65.

Natural Colouring Matters.

Wool Book II.
Acid Reds. 7. Lima-wood red (alumina mordant).
„ 8. Lima-wood red (tin mordant).
„ 9. Cam-wood red (alumina mordant).

NOTES.—The magentas are peculiar by becoming at first much bluer, so that at the end of the first 'fading period' they appear somewhat darker;

the purplish colour produced soon fades, however, and at the end of a year a pale grey remains. Acid magenta becomes duller but not bluer.

The rhodamines, pyronin G, and acridine red become yellower.

Cloth red 3 G extra and 3 B extra become distinctly yellower; ponceau 2 S extra becomes much bluer.

Cam-wood red is remarkable for becoming quite brown and appearing, therefore, darker at the end of the first fading period. This colour soon fades, however, and leaves at the end of a year a pale drab tint.

Class III. Moderately Fast Colours. (Wool.)

The colours of this class show distinct fading at the end of the second period (June 14 to July 21, 1892), which becomes more pronounced at the end of the third period (July 21 to August 14, 1892). A pale tint only remains at the end of the fourth period (August 14 to February 16, 1893), and at the end of a year's exposure the colour has entirely faded, or, at most, mere traces of colour remain.

Azo Colours.

Wool Book I.

Acid Reds. 3. Scarlet G. From xylidine and β-naphthol-di-sulphonic acid R. S. and J. 49.
„ 4. Scarlet B.
„ 5. Brilliant Scarlet GG. From *m*-xylidine and β-naphthol-di-sulphonic acid R. S. and J. 50.
„ 7. Lake Scarlet GG. Same as 5.
„ 10. Brilliant Scarlet G. Same as 3.
„ 11. Scarlet GR. From xylidine and β-naphthol-mono-sulphonic acid S. S. and J. 47.
„ 14. Lake Scarlet R. Same as 3.
„ 15. Ponceau R.
„ 17. Scarlet R. From *p*- and *m*-xylidine and β-naphthol-di-sulphonic acid R.
„ 21. Scarlet 2 R. Same as 5.
„ 22. Double Brilliant Scarlet 2 R.
„ 23. Pyrotin Red 3 RO. From β-naphthylamine-sulphonic acid D and α-naphthol-mono-sulphonic acid C.
„ 25. Persian Red.
„ 27. Croceïn Scarlet OXF. From naphthionic acid and β-naphthol-mono-sulphonic acid B. S. and J. 86.
„ 28. Ponceau 2 R. From amido-azo-benzene and β-naphthol-mono-sulphonic acid B and S. S. and J. 108.
„ 29. Cochineal Scarlet 2 R. From toluidine and α-naphthol-mono-sulphonic acid C. S. and J. 40.
„ 31. Cochineal Scarlet 4 R. From xylidine and α-naphthol-mono-sulphonic acid C. S. and J. 45.
„ 32. Ponceau 3 R. From amido-ethyl-dimethyl-benzene and β-naphthol-di-sulphonic acid R. S. and J. 51.
„ 33. Coccin BB.
„ 34. Naphthol Scarlet. From naphthionic acid and β-naphthol-sulphonic acid.
„ 37. Cochineal Scarlet R.
„ 38. Anisol Red. From ortho-anisidine and β-naphthol-mono-sulphonic acid S. S. and J. 54.
„ 39. Ponceau 4 R. From cumidine and β-naphthol-di-sulphonic acid R. S. and J. 51.
„ 40. Azo-eosin. From ortho-anisidine and α-naphthol-mono-sulphonic acid NW. S. and J. 55.
„ 41. Coccinin. From ortho-amido-phenetol and β-naphthol-di-sulphonic acid R. S. and J. 41.

Wool Book I.
Acid Reds. 42. Crystal Ponceau. From α-naphthylamine and β-naphthol-di-sulphonic acid G. S. and J. 64.
„ 49. Fast Red E. From naphthionic acid and β-naphthol-mono-sulphonic acid S. S. and J. 87.
„ 52. Cloth Scarlet G.
„ 64. Fast Red C. From naphthionic acid and α-naphthol-mono-sulphonic acid NW. S. and J. 85.
„ 66. Croceïn B. From amido-azo-benzene and α-naphthol-di-sulphonic acid Sch. S. and J. 107.
„ 67. Cloth Red G. extra. From amido-azo-toluene and β-naphthol-mono-sulphonic acid S. S. and J. 113.
„ 69. Bordeaux G. From amido-azo-toluene-mono-sulphonic acid and β-naphthol-mono-sulphonic acid S. S. and J. 126.
„ 70. Orchil substitute G. From para-nitraniline and β-naphthylamine-mono-sulphonic acid Br. S. and J. 37.
„ 71. Granat liquid. From α-naphthionic acid and α-naphthol-di-sulphonic acid (3·6).
„ 72. Cloth Red No. OG. Same as 67.
„ 74. Cloth Scarlet R.
„ 75. Buffalo Rubin. From α-naphthylamine and α-naphthol-di-sulphonic acid Sch. S. and J. 61.
„ 77. Œnanthin. From naphthionic acid and naphthol-di-sulphonic acid.
„ 79. Azo Red A. From amido-azo-naphthalene and α-naphthol-di-sulphonic acid.
„ 80. Wool Red.
„ 81. Fast Red D. From naphthionic acid and β-naphthol-di-sulphonic acid R. S. and J. 89.
„ 86. Palatine Red. From α-naphthylamine and naphthol-di-sulphonic acid. S. and J. 66.

Induline Colours. Rosindulines.

„ 78. Rosinduline B. Constitution not published.
„ 82. Rosinduline BB. Constitution not published.

Natural Colouring Matters.

Wool Book II.
Acid Reds. 3. Cochineal crimson (alumina mordant).
„ 4. Kermes crimson (alumina mordant).

Class IV. Fast Colours. (Wool.)

The colours of this class show comparatively little fading during the first, second, and third periods. At the end of the fourth period a pale shade remains, which at the end of the year's exposure still leaves a pale tint.

Azo Colours.

Wool Book I.
Acid Reds. 1. Ponceau 4 GB. From aniline and β-naphthol-mono-sulphonic-acid S. S. and J. 27.
„ 2. Ponceau 2 G. From aniline and β-naphthol-di-sulphonic acid R. S. and J. 29.
„ 6. Ponceau RT. From toluidine and β-naphthol-di-sulphonic acid R. S. and J. 42.
„ 8. Milling Red FGG. Constitution not published.
„ 13. Wool Scarlet R. From xylidine and α-naphthol-di-sulphonic acid Sch. S. and J. 46.
„ 18. Azo Coccin 2 R. From xylidine and α-naphthol-mono-sulphonic acid NW. S. and J. 44.
„ 19. Brilliant Croceïn MOO. From amido-azo-benzene and β-naphthol-di-sulphonic acid γ. S. and J. 109.

Wool Book I.

Acid Reds. 20. Palatine Scarlet. From *m*-xylidine and naphthol-di-sulphonic acid. S. and J. 48.

„ 24. Cotton Scarlet NT. From amido-azo-benzene and β-naphthol-di-sulphonic acid G.

„ 26. Croceïn Scarlet 3 B. From amido-azo-benzene-mono-sulphonic acid and β-naphthol-mono-sulphonic acid B. S. and J. 120.

„ 35. Double Brilliant Scarlet 3 R. From β-naphthylamine-sulphonic acid Br. and α-naphthol-mono-sulphonic acid NW. S. and J. 95.

„ 36. Cochineal Red A. From naphthionic acid and β-naphthol-di-sulphonic acid G. S. and J. 88.

„ 44. Fast Ponceau B. From amido-azo-benzene-di-sulphonic acid and β-naphthol. S. and J. 121.

„ 45. Milling Red FR. Constitution not published.

„ 46. Erythrin X. From amido-azo-benzene and β-naphthol-tri-sulphonic acid. S. and J. 111.

„ 47. Croceïn Scarlet 7 B. From amido-azo-toluene-mono-sulphonic acid and β-naphthol-mono-sulphonic acid B. S. and J. 125.

„ 48. Ponceau S extra. From amido-azo-benzene-di-sulphonic acid and β-naphthol-di-sulphonic acid R. S. and J. 122.

„ 51. Phœnix Red A. Constitution not published.

„ 53. Cloth Red G. From amido-azo-benzene and α-naphthol-mono-sulphonic acid NW. S. and J. 106.

„ 55. Ponceau 6 R. From naphthionic acid and β-naphthol-tri-sulphonic acid. S. and J. 90.

„ 56. Coccinin B. From amido-*p*-cresol-methyl-ether and β-naphthol-di-sulphonic acid R. S. and J. 56.

„ 57. Brilliant Croceïn 9 B. Constitution not published.

„ 63. Croceïn AZ. From amido-azo-benzene and α-naphthol-di-sulphonic acid.

„ 65. Erythrin P. From amido-azo-benzene and an unknown naphthol-sulphonic acid.

„ 85. Croceïn 3 B. From amido-azo-toluene and α-naphthol-di-sulphonic acid Sch. S. and J. 112.

„ 87. Cloth Red B. From amido-azo-toluene and α-naphthol-mono-sulphonic acid NW. S. and J. 115.

„ 91. Orseillin BB. From amido-azo-toluene-mono-sulphonic acid and α-naphthol-mono-sulphonic acid NW. S. and J. 124.

„ 93. Cloth Red No. OB. From amido-azo-toluene and β-naphthol-di-sulphonic acid R. S. and J. 114.

„ 97. Azo Fuchsin G. From sulphanilic acid and di-oxy-naphthalene (1·8)-α-mono-sulphonic acid. S. and J. 229.

„ 98. Azo Fuchsin B. From toluidine and di-oxy-naphthalene (1·8)-α-mono-sulphonic acid. S. and J. 228.

Wool Book II.

Chromotropes. 3. Chromotrope 6 B cryst. Constitution not published.

„ 4. Chromotrope 8 B cryst. Constitution not published.

„ 5. Chromotrope 10 B cryst. Constitution not published.

Induline Colours. Rosindulines.

Wool Book I.

Acid Reds. 95. Azo Carmine. Sodium salt of phenyl-rosinduline-di-sulphonic acid. S. and J. 369.

Class V. Very Fast Colours.

The colours of this class show a very gradual fading during the different periods, and even after a year's exposure a moderately good colour remains.

Azo Colours.

Wool Book II.

Chromotropes. 1. Chromotrope 2 R cryst. Constitution not published.

„ 2. Chromotrope 2 B cryst. Constitution not published.

Oxyquinone Colours.

5. Alizarin Red (alumina mordant).
10. Alizarin Turkey Red (cotton).

Natural Colouring Matters.

6. Madder red (alumina mordant).
1. Cochineal scarlet (tin mordant).
2. Kermes scarlet (tin mordant).

Silk Patterns.

The foregoing colours were dyed on silk, employing 2 per cent. colouring matter, and the patterns were exposed to light, along with those on wool, with the result that the relative fastness of the various colours was practically the same as on wool.

General Result.

The experiments extend at present over too limited a number of colouring matters to enable one to draw fixed general conclusions, but it may be well already at this point to record the following observations.

The most fugitive reds on wool and silk are the eosins and allied colours. Curiously enough, the introduction of the methoxy group, as in methyl-eosin, &c., increases the fastness, not of the colour as a whole, but of the pale faded tint which results after the first few weeks' exposure. As already stated, this tint remains practically unchanged even after a whole year's exposure. This is specially noticeable on the silk patterns.

With respect to the rosindulines, it is interesting to note that the G shades are very fugitive, while the B shades are moderately fast.

All basic reds belong to the more or less fugitive class, including, namely, the magentas, safranines, and rhodamines. The nature of the acid with which the colour base is combined seems to have no influence upon the fastness of the dyed colour.

Comparatively few (about twenty) of the azo reds examined are fugitive, and these belong chiefly to the simple monazo colours.

The great bulk of the fast and moderately fast reds belong to the azo colours, the so-called secondary disazo colours being generally faster than the rest. It is evident, however, that the fastness of these azo colours depends, not only upon the base which is azotised, but also upon the character of the naphthol-sulphonic acid employed. This is especially noticeable in the chromotropes, in which a particular dioxynaphthalene disulphonic acid is employed, and all of which are remarkable for their fastness. The particular azo compound and phenol united together is also of importance.

With respect to the milling and cloth reds, it does not appear that the use of mordants with them increases their fastness to light.

The number of very fast reds is extremely limited, but it includes both natural and artificial dyes—namely, madder, cochineal, kermes, alizarin, and the chromotropes 2 R and 2 B. When it becomes possible to expose the Congo reds, one or two others will no doubt have to be added to the list of very fast artificial red dyes. In this connection it may be pointed out that certain reds obtained from the natural dye-stuffs are fugitive, namely, those obtained from Lima-wood, Cam-wood, and the allied woods.

It is well to add that there are no sharp lines of division with respect to

fastness to light among the various reds, and each of the five classes into which they have been here arbitrarily divided includes colours which differ from each other more or less in this respect.

The Action of Light on the Hydracids of the Halogens in presence of Oxygen.—Report of the Committee, consisting of Dr. W. J. RUSSELL, Captain W. DE W. ABNEY, Professor W. N. HARTLEY, Professor W. RAMSAY, *and* Dr. A. RICHARDSON (*Secretary*).

SINCE the last report was presented the attention of the Committee has been directed to a consideration of the conditions necessary to start the decomposition of moist gaseous hydrogen chloride, and of aqueous solutions of the acid when exposed to the combined influence of sunlight and oxygen. It has been repeatedly noticed that, although decomposition of the gaseous mixture, when once started, proceeds at a fairly uniform rate in different samples, yet the time of exposure necessary to start the decomposition varies within very wide limits, although the conditions under which exposure is made appear to be the same in each case. It was also noticed that there was more difficulty in starting decomposition in hard than in soft glass tubes. This seems to indicate that the nature of the glass itself materially affects the initial stage of decomposition, which is dependent upon the length of time during which the acid has been kept in contact with the glass, as is borne out by such results as the following. Nine glass tubes having been filled with aqueous solutions of the acid of varying strength were exposed to sunlight. At the end of six months it was found that the most concentrated of these solutions had been decomposed, the others being unchanged, while after twelve months the three strongest of the remaining solutions showed by their yellow colour that they also had been decomposed.

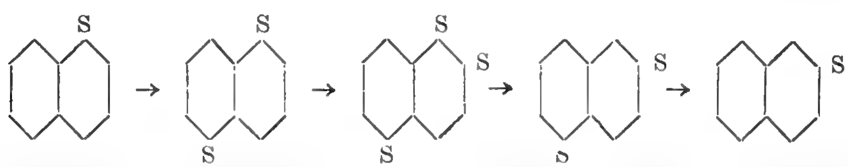
This is quite explicable on the ground that the stronger acid more rapidly dissolves out the constituents of the glass, and suggested that the presence of some metallic chloride is required to start the decomposition of the acid. Following up this line a large number of experiments have been made on the influence of metallic chlorides in promoting decomposition, and, although the results are not sufficiently advanced to allow of our giving full details at present, they appear fully to bear out the above hypothesis. For instance, it was found that the addition of a minute quantity of pure dry alumina to a tube containing moist hydrogen chloride and oxygen brought about rapid decomposition of the acid on exposure to light, while precisely similar samples to which no alumina had been added remained stable for long periods.

The Investigation of Isomeric Naphthalene Derivatives.—Seventh Report of the Committee, consisting of Professor W. A. TILDEN *and* Professor H. E. ARMSTRONG (*Secretary*). (*Drawn up by* Professor ARMSTRONG.)

IN previous reports attention has been over and over again directed to the *alpha-law of substitution* as the *dominant law* in the case of naphtha-

lene, and to the numerous apparent departures from this law observed in the formation of sulphonic acids. Most interesting examples of the formation of α-derivatives are afforded by Cleve's recent invaluable observations on the behaviour of the chlorides of ten of the chloronaphthalenesulphonic acids on nitration ('Öfversigt af Kongl. Vetenskaps-Akademiens Förhandlingar,' 1892, No. 9: presented November 9; 1893, Nos. 2, 3, and 5: presented February 8, March 14, May 9). His results are displayed in a subsequent diagram, in which also the properties of the various derivatives are indicated, as the Swedish publication in which they are described is not generally available. The formula of the chlorosulphochloride is given in the first column of symbols; that of the resulting nitro-derivative or derivatives in the second; and that of the corresponding trichloronaphthalene obtained by the action of phosphorus pentachloride in the third. In the table of β-derivatives the results obtained by Dr. Wynne and the writer on sulphonating the β-chlorosulphonic acids[1] are included for comparison with those obtained on nitrating their chlorides. It will be seen that in the case of the α-chloro acids the nitro-group in every instance takes up the 'opposite' α-position; only in two cases are β-compounds obtained. In the case of the β-chloro acids the nitro-group assumes the α-position *contiguous* to the β-chlorine atom—a most interesting and significant result.

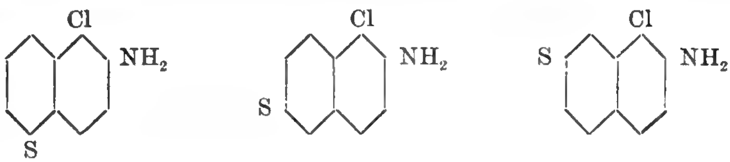
The results obtained on nitration are strikingly different from those attending sulphonation; it can scarcely be doubted, however, that in the case of sulphonic acids the formation of β-acids is due to secondary changes, but opinions differ as to the nature of these. It appears to be commonly supposed that when sulphonation takes place at high temperatures, and in presence of excess of acid, α-sulphonic groups become split off, and that sulphonation then occurs in β-positions; Dr. Wynne and the writer have been unable to discover any proof of direct sulphonation of the β-position, and incline to the belief that the formation of β-sulphonic derivatives is either the outcome of isomeric change or—and probably most frequently—of polysulphonation followed by hydrolysis. Thus, naphthalene-β-sulphonic acid is not improbably the final product of the following series of changes:



[1] The results of our examination of the sulphonation products of all the obtainable chloronaphthalenesulphonic acids are yet to be published. It may not be out of place to state that the work which was expressly reserved in 1890—the examination of the sulphonation products of the chloronaphthalenemonosulphonic acids (first notice, *Proc. Chem. Soc.*, 1890, p. 131), and of the corresponding naphthylaminemonosulphonic acids (first notice, *Proc. Chem. Soc.*, 1890, p. 128)—is nearly completed. As the object of the work is the determination of the positions assumed by the entering sulphonic radicle in the two classes of derivatives, there is little to be gained in publishing the results until the constitution of each disulphonic acid has been ascertained beyond question. This has involved characterising the trichloronaphthalenes more definitely than by melting-point determinations, and, as in the case of the dichloronaphthalenes (*Proc. Chem. Soc.*, 1890, p. 77; *Brit. Assoc. Rep.*, 1891), this is being carried out mainly by examining the acids obtained by sulphonating each of the fourteen isomeric trichloronaphthalenes (first notice, *Proc. Chem. Soc.*, 1890, p. 76).

We have in a previous report directed attention to the fact that the polysulphonic acids which can be obtained by sulphonation are of certain types, and that there is, in fact, an invincible objection on the part of two SO_3H groups—under conditions thereby prevailing—to remain in either contiguous, or para-, or peri-positions. During the year we have been able to examine three of the naphthalenedisulphonic acids which cannot be obtained by direct sulphonation, *i.e.*, the 1 : 2, 1 : 4, and 1 : 1′ acids, having prepared these, and the 2 : 3 : 2′-naphthalenetrisulphonic acid by an indirect method communicated to us by Dr. Duisberg.[1] With the aid of these acids and of others prepared by the same method we hope to further elucidate the phenomena of sulphonation.

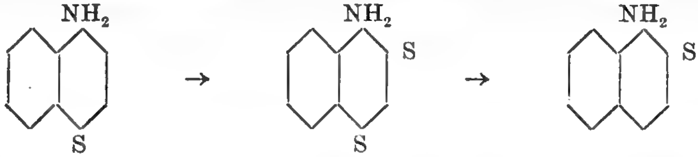
We have ascertained that of the three acids prepared by sulphonating chloro-β-naphthylamine hydrochloride, viz.—



No. 1. No. 2. No. 3.

Nos. 2 and 3 are of independent origin; in other words, that, although both can be obtained from No. 1, No. 2 is not convertible into No. 3 under the conditions which admit of the conversion of No. 1 into Nos. 2 and 3. It is noteworthy that, in the formation of the No. 2 and No. 3 acids, chloronaphthylaminedisulphonic acids always accompany the two monosulphonic acids, and the investigation of these compounds, so far as it has progressed, affords further evidence in favour of our view of the complexity of the phenomena underlying the formation of β-sulphonic acids.[2]

Another case which may be referred to is that of the formation of 1 : 2 α-naphthylamine β-sulphonic acid from naphthionic acid (1 : 4), which is effected by heating the sodium salt of the latter at about 200°. It appears probable to us that the change involves the formation of a disulphonic acid, which then undergoes hydrolysis, yielding the ortho-acid, thus:—



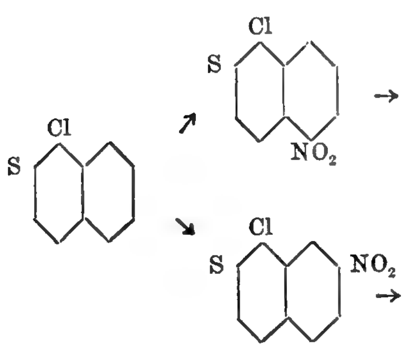
The production of disulphonic acid may be the outcome either of direct interaction of two molecules of the monosulphonic acid or of the action of acid sulphate formed by the agency of traces of water unavoidably present in the salt. It has actually been observed that hydrated potassium 1 : 2 : 4 α-naphtholdisulphonate yields the ortho-mono-sulphonate when heated.[3] The superior stability of the ortho- as compared with the para-sulphonate thus brought into evidence in the case of both naphthol and naphthylamine is highly remarkable, bearing in mind the extreme instability of the corresponding benzene derivatives, and is evidence that the

[1] Cf. *Chem. Soc. Proc.*, 1893, p. 166.
[2] *Ibid.*, 1890, p. 133.
[3] *Cf.* Conrad and Fischer, *Liebig's Annalen.*

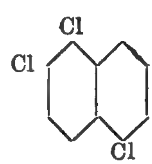
mere contiguity of an amido- or hydroxyl-group does not condition instability. The special properties of the β-sulphonic derivatives of naphthalene are doubtless a consequence of a structural peculiarity of the cycloid. It is especially from this last point of view that observations such as are here alluded to are of particular interest, and it may be permitted to draw attention to them as illustrating the circumstance that facts which in themselves are of no special value may become of more than usual interest when considered in connection with the larger problems underlying all investigations of details.

In the course of the further study of the action of bromine on beta-naphthol derivatives interesting results have been obtained which may be here mentioned. If an aqueous solution of potassium 2 : 2′ beta-naphthol-sulphonate be subjected to the action of even a large excess of bromine, potassium bromohydroxynaphthaquinone sulphonate is produced, together with a very small proportion of dibromohydroxynaphthaquinone; but if an aqueous solution of this quinone sulphonate be warmed with bromine it becomes oxidised to a brominated sulphophthalic acid; apparently, in the former case, the presence of hydrogen bromide in excess prevents the bromine acting as an oxidising agent. It is easy to obtain a monobromosulphonate and the quinone sulphonate by the action of bromine on an aqueous solution of Schaeffer's salt, but the preparation of the intermediate di- and tri-bromosulphonates is very difficult. If, however, the *salt* be suspended in muriatic acid it is easy to convert it wholly into tribromosulphonate and to avoid the production of quinone sulphonate. Recently it has been ascertained that if 2 : 3′ beta-naphtholsulphonic *acid* be dissolved in muriatic acid it is wholly converted into tetra-bromo-beta-naphthol by the mere addition of an excess of bromine; as the product of the action of an excess of bromine on beta-naphthol is a mixture of the tri- and tetra-bromo-derivative, which are separated only with difficulty, this observation affords a welcome method of preparing tetra-bromo-beta-naphthol. The readiness with which bromine, in presence of muriatic acid, displaces the sulphonic radicle from the acid, but not from the salt, is calculated to excite surprise.

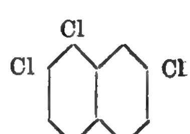
α-Chloro-derivatives



Melting-point of Chloro-nitro-sulphonic		
Chloride	Amide	Ethylic salt
151°	220°	116°
182°	231°	—

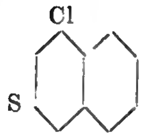
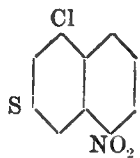
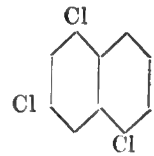
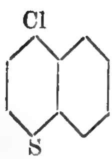
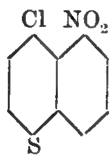
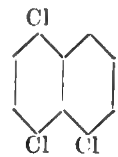
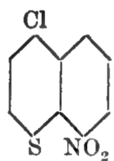
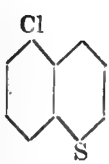
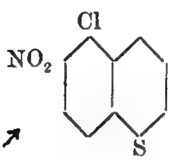
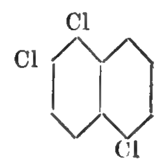
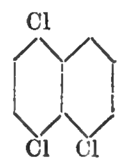
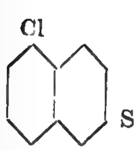
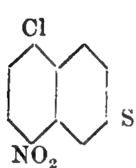
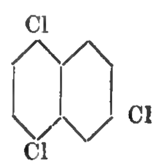
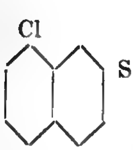
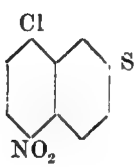
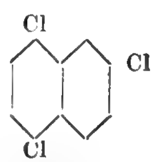
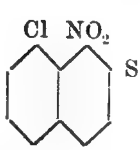
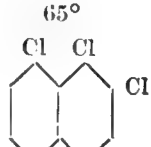


77°

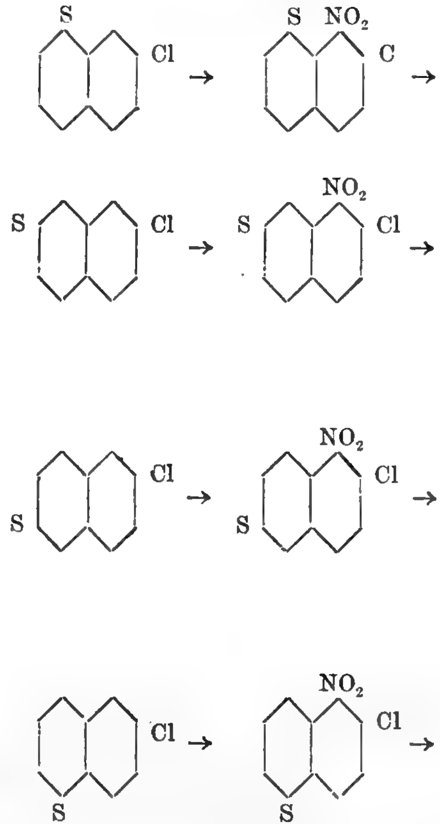


75°

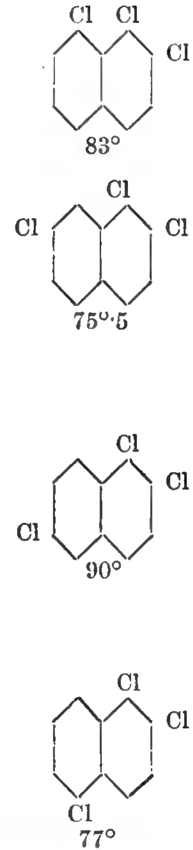
a-Chloro-derivatives

		Melting-point of Chloro-nitro-sulphonic			
		Chloride	Amide	Ethylic salt	
		130°	188°	—	 103°
		127°	181°	—	 130°
		150°	233°	—	
		118°	220°	—	 76°
		134°	—	—	 130°
		161°	188°	123°	 65°
		116°	208°	89°	 65°
		129°	245°	124°	 81°

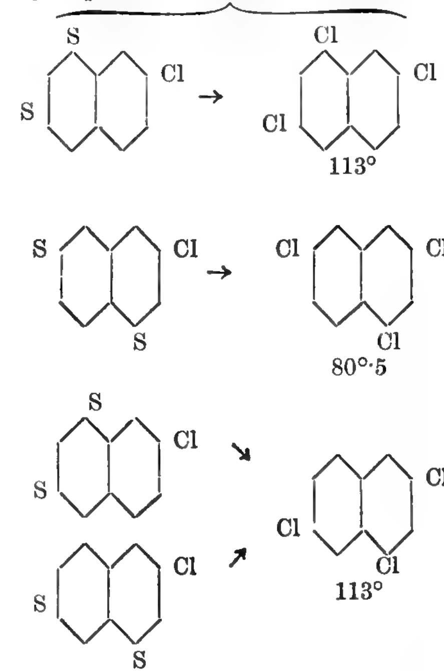
β-Chloro-derivatives



Melting-point of Chloro-nitro-sulphonic		
Chloride	Amide	Ethylic salt
190°	226°	181°
219°	247°	184°
161°	203°	139°
112°	214°	110°



Chloronaphthalenedisulphonic acids and derived trichloronaphthalenes obtained by sulphonation of β-chloro-acids



Wave-length Tables of the Spectra of the Elements and Compounds. —*Report of the Committee, consisting of* Sir H. E. ROSCOE, Dr. MARSHALL WATTS, Mr. J. N. LOCKYER, Professors DEWAR, LIVEING, SCHUSTER, W. N. HARTLEY, *and* WOLCOTT GIBBS, *and* Captain ABNEY. (*Drawn up by* Dr. MARSHALL WATTS.)

AIR (SPARK SPECTRUM).

Neovius ('Bihang till K. Svenska Vet. Akad. Handlingar,' Bd. xvii. 1891).

Trowbridge and Hutchins give also strong air-lines at 4816·60, 4802·37, 4782·62, 4694·15, 4638·90, 4583·15.

* double. § probable impurity. Th. Thalén.
T. & H. Trowbridge and Hutchins. H. Huggins.
[1] Intensity of oxygen line 4. † Probably due to copper.

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
5768·5 N	3	5768·3 Th.	17330
5747·5 N	3	5746·4 „	17394
5731·5 N	1	5727·4 „	17442
5712·3 N	6	5712·3 „	17501
5686·3 N	5	5686·7 „	17581
5679·8 N	12	5679·4 „	17601
5676·0 N	5	5675·9 „	17613
5667·1 N	9	5667·4 „	17640
5593·0§	<1		17874
5566·0 N	<1		17961
5551·0 N	3	5550·1 „	18009
5543·0 N	3	5542·3 „	18035
5535·2 N	6	5535·3 „	18061
5530·4 N	3	5531·1 „	18077
5526·4 N	1		18090
5496·6 N	6	5496·2 „	18188
5479·8*N	5b	5480·1 „	18243
5462·8 N	5	5462·7 „	18300
5453·8*N	5	5454·1 „	18330
5432·3 N	<1		18403
5411·1 N	1		18475
5401·0 N	<1		18510
5393·5 N	1		18535
5379·0§N	<1		18585
5373·2§N	<1		18605
5367·8§N	<1		18624
5356·9 N	1		18661
5351·7 N	1	5352·1 „	18680
5339·7 N	1	5340·5 „	18722
5329·1 N	1		18759
5320·6 N	1	5321·0 „	18789
5312·0	<1		18819
5289·0§	<1		18901
5281·8 N	1		18927
5250·7 N	<1		19038
5213·8§	<1		19174
5206·7 O	<2	5206 H.	19200
5200·9 N	1		19221
5190·8*NO	1	5190·6	19259
5185·0*N	1	5185·6	19281

AIR (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
5180·0 N	5	5179·1	19299
5176·7*NO	1		19312
5172·5*N	1	5172·8	19327
5161·0 O	1	5164 H.	19370
5074·0 N	1	5072 ,,	19703
5063·0 N	<1		19745
5045·7 N	7	5045·7 Th.	19813
5025·8 N	3	5025·7 Th.	19891
5023·3 N	3	5022·95 T. & H.	19901
5016·5 N	3	5016·8 Th.	19928
5011·0*N	5	5011·06 T. & H.	19950
5007·8 N	5	5007·5 Th.	19963
5005·7 N	10	5006·0 ,,	19978
5002·7 N	10	5003·0 ,,	19983
4994·9 N	6	4994·4 ,,	20014
4991·2 N	1		20022
4987·6 N	4	4987·7 ,,	20044
4965·3 N	<1		20134
4955·2 O	1	4955·16 T. & H.	20167
4942·7*	3	4942·0 Th.	20226
4935·1*N	2	4932 H.	20257
4925·2 O	2	4925·3 ,,	20298
4915·0 N	<1	4915·12 T. & H.	20340
4907·3 O	2	4907·67 ,,	20372
4896·5 N	4	4896·6 Th.	20417
4891·5 O	1	4891·27 T. & H.	20438
4879·7 N	2	4879·90 ,,	20487
4872·0 O	1	4873 H.	20519
4867·0 N	1	4867 ,,	20540
4861·0*N	3b	4859 ,,	20566
4856·3 O	1	4854 ,,	20586
4848·0 N	1	4850 ,,	20621
4810·8 N	3		20780
4806·2 N	3		20800
4803·6 N	7	4804·7 Th.	20811
4794·2 N	3	See Iron	20853
4788·5 N	6	4788·27 T. & H.	20877
4780·1 N	5	4780·1 Th.	20914
4774·6 N	3	4775·07 T. & H.	20938
4768·2§	<1		20966
4765·1 N	2		20980
4752·0 O	2b		21038
4742·1 O	1		21081
4736·1 N	3		21108
4726·8 N	3		21150
4721·9 N	1		21172
4718·5 N	3		21187
4712·5 N	<1	4712·87? T & H.	21213
4710·1 O	5	4710·20 ,,	21225
4709·7 N	<2		21226
4705·6 O	6	4705·42 ,,	21245
4705·0 N	<2		21248
4699·7 O	6	4699·40 ,,	21272
4698·0 N	<1n		21279
4696·0*NO	<2b		21288
4692·0 O	<1		21307
4676·5 O	6	4676·4 ,,	21377
4674·8 N	4	4674·9 ,,	21385

AIR (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
4670·9*N	3n		21403
4668·1 N	3		21416
4661·9 O	5	4662·6 Th.	21444
4658·1 N	1	4658·05 T. & H.	21462
4654·8 N	3	4654·85 ,,	21477
4651·0 NO	4	4651·02 ,,	21494
4649·2 O	8	4649·25 ,,	21503
4643·4 N	9	4643·45 ,,	21529
4641·9 O	9	4641·90 ,,	21536
4640·5 N	1	4640·75 ,,	21543
4639·0 O	5	4639·00 ,,	21550
4634·0 N	3	4634·00 ,,	21573
4630·9 N	12	4630·73 ,,	21588
4622·0 N	9	4621·42 ,,	21629
4614·2 N	8	4614·05 ,,	21666
4609·6 NO	2	4609·45 ,,	21687
4607·2 N	8	4607·20 ,,	21699
4601·3 N	9	4601·37 ,,	21726
4596·6 O	6	4596·20 ,,	21749
4591·1*O	7b	{ 4590·95 ,, 4590·00 ,,	21776
4579·2 N	2	4578·55 ? ,,	21831
4565·0 N	2		21899
4552·6 N	3n		21959
4545·1 N	3	4544·50 ? ,,	21995
4535·1 N	<1		22043
4530·3 N	6b		22067
4523·0 N	1b		22103
4518·0 N	<1		22127
4514·8 N	3		22143
4511·6 N	1	4511·85 ,,	22158
4507·7 N	6	4507·72 ,,	22178
4491·2 O	<1b		22259
4488·0 N	<2	4487·94 ,,	22275
4482·1 N	1	4481·87 ,,	22309
4478·0 N	3	4477·87 ,,	22325
4475·0 N	1b		22340
4469·6 O	3n	4469·50 ,,	22367
4467·8 O	4	4468·02 ,,	22376
4465·4*O	4	4465·40 ,,	22388
4460·0 N	3	4459·90 ,,	22415
4452·7 O	3	4452·40 ,,	22452
4447·3*NO [1]	12	4447·09 ,,	22479
4443·2 O	1	4443·0 ,,	22500
4434·4 N	3	4434·27 ,,	22544
4432·0 N	3b	4431·90 ,,	22556
4430·4 N	3	4430·04 ,,	22566
4426·1 N	5	4426·00 ,,	22587
4417·3 O	9	4417·17 ,,	22632
4415·0 O	9	4415·00 ,,	22643
4401·3 N	3n	4401·22 ,,	22714
4396·1 O	3n	4396·30 ,,	22741
4392·4 N	<1		22760
4385·8 N	<1	4385·40 ,,	22794
4379·7 N	3	4379·70 ,,	22826
4375·2 N	1		22849
4371·4*N	3	4371·40 ,,	22869
4369·7 O	3	4369·60 ,,	22887

AIR (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
4368·8 O	3		22883
4367·0 O	6	4366·92 T. & H.	22892
4362·1 N	<1		22918
4356·7 N	1b	4356·62 ,,	22946
4351·6 O	6	4351·40 ,,	22973
4349·4 O	8	4349·30 ,,	22985
4347·9*NO	6	{ 4347·94 ,, / 4347·47 ,, }	22993
4345·8 O	6	4345·52 ,,	23004
4341·8 N	1b		23025
4337·1 O	3		23050
4331·7*NO	3n	{ 4332·40 ,, / 4331·20 ,, }	23079
4328·5 O	1	4328·42 ,,	23096
4327·3 O	3	4327·60 ,,	23102
4325·9 O	3	4325·90 ,,	23110
4319·9 O	4	4319·50 ,,	23142
4317·1 O	4	4317·20 ,,	23157
4303·4 O	1b	4303·80 ,,	23230
4292·0 O	1b	4291·90 ? ,,	23292
4282·9*NO	1b	4282·40 ,,	23342
4275·2 NO	1	4274·82 ,,	23384
4266·7 N	<2	4266·32 ,,	23430
4254·1 O	1b	4253·42 ,,	23500
4251·0 N	1		23517
4242·1 N	6b	4241·92 ,,	23566
4237·0 N	6b	4236·67 ,,	23595
4228·9 N	6b	4228·52 ,,	23640
4225·1 N	1		23661
4223·4 N	4	4223·17 ,,	23671
4222·2 N	1		23677
4219·2 N	<1		23694
4215·6 N	1b	4217·0 H. & A.	23714
4211·4 N	1		23738
4207·2 N	1b	4206·92 T. & H.	23762
{ 4198·2 N	4b	4199·22 ,,	23813
4196·5 N }	4s		23822
4193·2 N	1	4193·77 ,,	23841
4190·0 O	7	4190·00 ,,	23859
4185·8 O	7	4185·32 ,,	23883
4180·3 N	<2n	4179·92 T. & H.	23915
4176·7 N	5b	4177·4 H. & A.	23936
4172·0 N	<2	4172·12 T. & H.	23962
4169·5 O	3	4169·47 ,,	23977
4167·2 N	1	4166·72 ,,	23990
4158·4 N	1	4158·6 H. & A.	24041
4156·7 O	3	4156·79 T. & H.	24050
4153·7 O	6	4153·57 ,,	24068
4152·0 N	5	4151·92 ,,	24078
4145·9*NO	7	4145·87 ,,	24113
4143·8 O	4		24125
4142·8 N	<1		24131
4142·4 O	1		24133
4140·7 N	<1		24143
4137·8 N	1b	4137·7 Th.	24164
4134·2 N	6	4133·79 T. & H.	24181
4132·9 O	6	4132·82 ,,	24189
4129·3 O	1		24210

AIR (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
4124·0 NO	5	4123·82 T. & H.	24241
4121·8 O	4	4121·56 ,,	24254
4120·6 O	6	4120·46 ,,	24261
4119·4 NO	9	4119·36 ,,	24268
4116·8 N	<1		24283
4114·2 O	1		24299
4112·4 O	3	4112·16 ,,	24309
4111·0 O	2	4111·01 ,,	24318
4105·2 O	4b	4105·21 ,,	24352
4103·4*N	4b	4103·3 H. & A.	24363
4097·3*NO	8b	4097·49 T. & H.	24399
4093·1 O	4	4093·09 ,,	24416
4089·3 O	1b	4088·64 ,,	24447
4085·3 O	3	4085·24 ,,	24470
4081·7 N	1		24492
4079·1 O	3	4078·83 ,,	24508
4076·3 O	9	4076·19 ,,	24525
4072·4 O	9	4072·34 ,,	24548
4070·1 O	8	4070·24 ,,	24562
4063·7 N	1	4064·1 H. & A.	24601
4056·8 N	1b	4057·9 ,,	24643
4041·5 N	6b	4041·39 T. & H.	24736
4035·2 N	5b	4035·34 ,,	24774
4025·9 N	2b	4026·2 H. & A.	24832
4019·4	<1		24871
4014·3 N	1		24903
4011·1	<1	4011·34 T. & H.	24923
3995·2 N	12	3995·10 ,,	25022
3982·9 O	4	3982·97 ,,	25101
3973·5 O	<2	3973·60 ,,	25159
3968·6 N	1	3968·70 ,,	25191
3961·6 O	1		25234
3956·1 N	7	3956·17	25270
3954·6 O	5	3954·85	25272
3947·5 O	3		25325
3945·3 O	4	3945·3 H. & A.	25339
3939·7 N	<2b	3939·80 T. & H.	25375
3934·7 N	1b	3935·10 ,,	25400
3928·8	<2	3929·8 H. & A.	25445
3919·2*NO	10	3919·25 T. & H.	25507
3912·2 O	5	3912·30 ,,	25553
3909·2 N	1		25573
3907·8 O	1		25581
3898·9 O	1b		25640
3893·4 N	1b	3893·50 ,,	25676
3882·6 O	3	3882·45 ,,	25748
3875·9 O	1		25793
3864·7 O	3	3864·90 ,,	25867
3863·6 O	2	3863·80 ,,	25875
3861·7 N	3		25888
3860·5†	3		25896
3857·2 NO	4b	3857·40 ,,	25918
3851·6 O	2		25956
3850·6 N	3	3850·70 ,,	25962
3848·1 NO	1n		25979
3845·3 N	3		25998
3844·0 O	1		26007
3843·1*N	<2	3843·00 ,,	26013

AIR (SPARK SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Oscillation Frequency in Vacuo
3839·8 N	<2b	3839·28 T. & H.	26035
3831·0 N	1b	3830·60 „	26095
3824·4 O	1n	3824·4 H. & A.	26140
3809·9 N	<1		26239
3804·3 O	1n	3804·4 „	26278
3782·3 N	<1	3782·7 „	26431
3779·1 O	<1		26447
3770·9 N	1	3772·1 „	26511
3764·6 O	<1		26555
3759·9 O	1	3759·9 „	26588
3758·5 N	1		26598
3757·1 O	1		26608
3754·6 O	1n	3754·0 „	26626
3749·7 O	6	3749·80 T. & H.	26661
3744·4	<1		26698
3741·3 O	<1	3740·3 H. & A.	26721
3736·9 O	<1		26752
3729·4 N	3		26806
3727·4 O	5	3727·0 „	26820
3712·9 O	3	3712·7 „	26925
3709·3 O	<1		26951
3707·2 O	<1		26966
3703·3 O	<1	3702·4 „	26995

COPPER (ARC SPECTRUM).

Kayser and Runge (‘Ueber die Spectren der Elemente,’ Pt. V. Berlin, 1892).

* See Iron. † ‘Bihang till K. Sv. Vet. Akad. Handl.,’ xvii. p. 69. Neovius gives also lines at 4758·5, 4556·2, 4228·0, 4043·8. ‡ See Barium.
§ See Calcium. ¶ See Mercury. ‖ See Zinc.
** See Bismuth. †† See Cadmium.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda +$	$\frac{1}{\lambda} -$	
*5782·30	0·03	8s	5782·5 Neovius †	5782·4 Th.	1·70	5·1	17289·0
5732·53	0·03	1s			1·69	„	17439·2
5700·39	0·03	8s	5700·8 „	5701·8 „	1·68	5·2	17537·5
5646·93	0·30	1n			1·67	„	17703·5
*5555·16	0·10	4s			1·64	5·3	18996·0
5536·06	0·40	4b			„	„	18058·1
5432·30	0·15	2n			1·61	5·4	18393·9
5408·56	0·15	2n			1·60	5·5	18483·7
*5391·89	0·15	4n			1·59	„	18540·9
5360·22	0·05	2s			„	„	18650·8
5355·20	0·20	2n			1·58	5·6	18667·8
5352·87	0·05	2s			„	„	18676·0
5292·75	0·05	6s	5293·0 „	5293·1 Th.	1·57	„	18888·2
*5250·78	0·15	2b			1·55	„	19039·2
5220·25	0·05	6s			„	5·7	19150·5
5218·45	0·10	10b'r 4*	5218·4 „	5218·1 „	„	„	19157·1
5201·10	0·10	4b			1·54	„	19221·0

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)		Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
5158·53	0·15	1b			1·53	5·7	19379·7
5153·33	0·20	8nr 4*	5153·6 Neovius	5153·3 Th.	,,	5·8	19399·1
5144·35	0·15	2b			1·52	,,	19433·0
5105·75	0·05	8r	5105·9 ,,	5105·5 ,,	1·51	,,	19580·0
5076·42	0·15	2b			1·50	,,	19693·1
5034·48	0·15	1b			1·49	,,	19857·2
			4955·8 ,,	4956·5 ,,			
4866·38	0·20	2n	4932·5 ,,	4933·4 ,,	1·44	6·1	20543·1
4794·23	0·20	2n	4911·0 ,,	4912·3 ,,	1·42	6·2	20852·2
4767·69	0·20	2n			,,	,,	20968·3
4704·77	0·05	8s	4703·2 ,,	4704·0 ,,	1·40	6·3	21248·7
4697·62	0·10	4n			1·39	,,	21281·1
4674·98	0·10	6b			,,	6·4	21384·1
4651·31	0·10	8s	4651·3 ,,	4651·5 ,,	1·38	,,	21492·9
4642·78	0·15	2n			,,	,,	21532·4
4587·19	0·15	10n	4587·4 ,,		1·36	6·5	21793·3
4539·98	0·15	8br	4540·1 ,,		1·35	6·6	22019·9
4531·04	0·10	$8b^{v}r$ 4†	4531·1 ,,		,,	,,	22063·4
4513·39	0·10	2b			1·34	,,	22149·7
4509·60	0·05	4s	4509·9 ,,		,,	,,	22168·3
4507·62	0·20	6n			,,	,,	22178·1
4480·59	0·10	$8b^{v}r$ 4†	4480·6 ,,		1·33	,,	22311·9
4415·79	0·10	6b			1·32	6·7	22639·3
4397·42	0·15	1n			1·31	6·8	22733·8
4378·40	0·05	8r	4378·2 ,,		,,	,,	22832·6
4354·91	0·20	2n			1·30	6·9	22955·7
4336·17	0·10	2b			1·29	,,	23054·9
4329·00	0·15	2n			,,	,,	23093·1
4275·32	0·05	8r	4275·3 ,,	4275·5 ,,	1·28	7·0	23383·1
4267·48	0·15	1b			1·27	,,	23426·0
4259·63	0·10	6b			,,	,,	23469·2
4253·53	0·10	2b			,,	,,	23502·9
4249·21	0·05	4s	4249·4 ,,		,,	,,	23526·8
4242·42	0·10	2b	4242·7 ,,		,,	,,	23564·5
4231·20	0·10	1n			1·26	,,	23627·0
4177·87	0·10	4b			1·25	7·1	23928·5
4123·38	0·10	2b			1·23	7·2	24244·7
4080·70	0·10	2n			1·22	7·3	24498·3
4073·28	0·15	2n			,,	7·4	24542·8
4063·50	0·20	1n	4063·0 ,,		,,	,,	24601·9
4062·94	0·10	$10b^{v}$ 5*			,,	,,	24605·3
4056·8	0·50	$2b^{r}$			,,	,,	24642·6
4022·83	0·10	$10b^{v}$ 5*	4022·9 ,,		1·21	7·5	24850·6
4015·8	0·50	$1b^{r}$			1·20	,,	24894·1
4010·96	0·20	2n			,,	,,	24924·2
4003·18	0·05	2s			,,	,,	24972·6
3925·40	0·05	2b			1·18	7·4	25467·7
3921·38	0·05	1b			1·18	7·7	25493·7
3899·43	0·10	1b			1·17		25637·1
‡3861·88	0·20	2b 5†			1·16	7·8	25887·3
3860·64	0·05	4b	3850·7 ,,				25894·6
3825·13	0·20	1b 5†			1·15	7·9	26135·0
3821·01	0·05	1b					26163·2
*3812·08	0·05	1b					26224·5
3805·33	0·05	2b			1·14		26271·0

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	1/λ −	
3771·96	0·05	4b		1·14	8·0	26503·4
3759·53	0·05	2b		1·13	8·1	26591·0
3741·32	0·05	4b		1·13		26720·4
3734·27	0·05	2b		1·13		26770·9
3712·05	0·05	2b		1·12		26931·2
3700·63	0·05	4b		,,	8·2	27014·2
3688·60	0·25	2n 6*	3686·6 Nevius	1·11		27102·4
3684·75	0·05	2b				27130·7
3676·97	0·05	2b				27188·1
3672·00	0·05	2b				27224·9
3665·85	0·05	2b			8·3	27270·5
3659·44	0·05	1b		1·10		27318·3
3656·90	0·05	1b				27337·3
3655·99	0·05	2				27344·1
3654·6	0·50	2n 6*				27354·5
3652·56	0·15	1n				27369·8
3648·52	0·05	1b				27400·1
3645·32	0·05	2b				27424·1
3641·79	0·05	2b				27451·7
3636·01	0·05	2b				27494·4
3627·39	0·05	4b			8·4	27559·6
3624·35	0·05	2b				27582·8
3621·33	0·05	4b		1·09		27605·8
3620·47	0·05	2b				27612·3
3614·31	0·05	1b				27659·4
3613·86	0·05	2b				27662·8
3602·11	0·10	6b	3599·7			27753·1
3599·20	0·10	6b	3597·7 H. & A.			27775·6
3546·54	0·05	1b		1·07	8·6	28187·9
3545·05	0·05	2b				28199·7
3533·84	0·05	4b				28289·2
3530·50	0·05	4				28316·0
3527·55	0·05	4b				28339·7
3524·31	0·10	2b	3524·4 ,,			28365·7
3520·07	0·05	4b				28399·9
3512·19	0·05	6b	3511·1 ,,	1·06	8·7	28463·6
3500·37	0·05	1b				28559·7
*3498·11	0·05	2b				28578·2
3488·89	0·05	1b				28653·7
§3487·62	0·05	1b				28664·1
3483·82	0·05	4b	3483·2			28695·4
3476·07	0·05	4b	3478·8 ?			28759·4
3454·76	0·05	4b	3455·8	1·05	8·8	28936·8
*3450·47	0·10	6b	3450·1			28970·3
3422·22	0·10	2n		1·04	8·9	29211·9
3420·20	0·05	1b				29229·2
3415·94	0·10	2b				29265·6
3413·41	0·05	2b				29287·3
3404·73	0·05	2b			9·0	29361·9
*3402·28	0·05	2b		1·03		29383·1
3396·39	0·05	1				29434·0
3395·52	0·05	2b				29441·6
3393·09	0·05	2				29462·7
3392·10	0·05	1				29471·3
3391·09	0·05	2n				29480·0

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3388·21	0·15	1b				29505·1
3384·88	0·05	2b				29534·1
3381·52	0·05	4b	3381·0 H. & A.	1·03	9·0	29563·5
3375·74	0·05	2b				29614·1
3365·46	0·10	4b		10·2	9·1	29704·5
3354·57	0·10	2b				29801·0
3349·38	0·10	4b				29847·2
3342·99	0·15	1n				29904·2
3337·95	0·05	4			9·2	29949·3
3329·68	0·05	4b		1·01		30023·7
3319·76	0·05	4b				30113·5
3317·28	0·05	4b				30136·0
3308·10	0·05	8b	3306·8 ,,			30219·6
3292·95	0·05	2			9·3	30358·6
3290·62	0·05	6n	3289·9 ,,	1·00		30380·1
3282·78	0·05	4b	3282·1 ,,			30452·7
3279·89	0·05	2	3280·1 ? ,,			30488·8
3277·35	0·05	1				30503·2
3274·06	0·03	10r	3273·2 ? ,,			30533·8
3266·05	0·05	2b	3265·2 ,,		9·4	30608·6
3247·65	0·03	10r	3246·9 ,,	0·99		30782·1
3243·21	0·05	4b	3243·9 ? ,,			30824·3
3235·74	0·05	4b	3233·4 ? ,,			30895·4
*3231·19	0·05	4b			9·5	30938·8
3226·61	0·05	2b		0·98		30982·8
3224·69	0·05	2b				31001·2
3223·47	0·05	2b				31013·0
3211·47	0·10	2				31128·9
3208·32	0·05	4				31159·5
3194·17	0·05	4		0·97	9·6	31297·4
3175·81	0·10	2n				31478·4
3169·73	0·05	4b				31538·8
3160·09	0·05	2			9·7	31635·0
3151·67	0·05	2b		0·96		31719·6
3146·93	0·05	4n				31767·3
*3142·47	0·05	4n				31812·4
3140·42	0·05	4b	3139·7 ? ,,			31833·2
3128·73	0·05	4b			9·8	31952·0
*3126·22	0·05	6b	3123·7 ,,			31977·7
*3120·53	0·05	2b		0·95		32036·0
3116·48	0·05	4b	3115·7 ,,			32077·7
3113·59	0·05	2b				32107·5
3108·64	0·05	6b	3107·4 ,,			32158·6
3099·97	0·05	4b	3097·8 ,,		9·9	32248·5
3094·07	0·05	2				32310·0
3073·89	0·05	4		0·94		32522·2
3070·86	0·10	1b			10·0	32554·2
3063·50	0·05	6				32632·4
3057·73	0·05	2				32694 0
3053·52	0·10	1b				32739·1
3052·73	0·10	1b				32747·6
3044·18	0·05	2b		0·93		32839·6
3036·17	0·05	6	3035·6 ,,		10·1	32926·1
*3030·33	0·10	2b				32989·6
3025·07	0·10	2b				33047·0

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}-$	
3022·65	0·10	4b	3023·4 H. & A.			33073·5
¶3021·73	0·10	2b				33083·5
3012·07	0·05	4b		0·92	10·2	33189·6
3010·92	0·05	4				33202·2
§2997·46	0·05	4				33351·4
2991·91	0·10	2n			10·3	33413·2
2986·10	0·10	4n				33468·7
2982·91	0·10	2n				33514·0
2979·52	0·10	2n				33552·2
2978·42	0·10	2n				33564·6
2961·25	0·10	6r	2959·6 ,,	0·91	10·4	33759·1
2951·38	0·10	4b			10·5	33872·0
¶2925·65	0·10	2b		0·90	10·6	34169·8
2924·99	0·10	1b				34187·5
2911·29	0·10	2				34338·4
2891·77	0·10	2n		0·89	10·7	34570·2
2890·97	0·10	2n				34579·8
2883·03	0·05	4	2882·4 ,,			34675·0
2879·04	0·20	2n	2877·4 ,,			34723·1
2875·66	0·20	2n			10·8	34763·8
2874·60	0·20	2n				34776·6
2792·07	0·10	2n		0·87	11·1	35804·6
2786·65	0·10	2n			11·2	35874·2
2783·67	0·10	2n		0·86		35912·6
2782·73	0·10	2n				35924·7
2769·37	0·20	1b				36097·1
2768·94	0·10	4b	2769·1 ,,			36103·7
2766·50	0·05	6b^{v}r	2766·2 ,,			36135·6
2751·86	0·20	1b			11·3	36328·1
‖2751·38	0·10	4n				36334·1
2724·04	0·10	4n	2721·2 ,,		11·4	36698·8
2715·67	0·10	4n	2713·1 ,,	0·85	11·5	36811·8
**2696·83	0·15	1b		0·83	11·6	37069·0
2687·85	0·15	1b	2688·8 ,,			37192·9
2681·16	0·15	1b				37285·7
2676·59	0·10	2b^{v}		0·84	11·7	37349·3
2672·24	0·15	2n		0·83		37410·1
*2651·78	0·10	2n			11·8	37698·7
2649·93	0·10	2n	2643·5 ,,			37725·0
2645·45	0·10	2n				37788·9
‡2635·02	0·10	4n		0·82	11·9	37938·5
2630·15	0·10	4n				38008·7
2627·49	0·10	2n				38047·2
2618·46	0·05	10r	2617·8 ,,		12·0	38178·4
2605·08	0·15	1n				38374·5
2580·52	0·05	2n		0·81	12·2	38739·7
2579·40	0·05	2n				38756·5
2570·76	0·05	2b				38886·8
2569·99	0·05	2n				38898·5
2567·17	0·05	1b^{v}	2565·3 ? ,,			38941·2
*2563·54	0·05	2b^{v}		0·80		38996·4
2553·38	0·05	1b^{v}	2552·2 ,,		12·3	39151·5
2547·67	0·05	2b^{v}	2544·6 ,,		12·4	39239·2
2494·97	0·05	2	2494·4 ,,	0·79	12·6	40068·0
2492·22	0·05	6r	2489·4 ,,			40112·3

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2460·98	0·15	2b		0·78	12·8	40621·4
*2458·97	0·15	2b	2458·2 H. & A.			40654·6
2441·72	0·05	6r	2441·6 „	0·77	12·9	40941·8
*2406·82	0·15	8b^v	2404·3 „	0·76	13·2	41535·4
2400·18	0·05	4	2400·1 „			41650·3
2392·71	0·05	8b^{v}r	2392·2 „		13·3	41780·3
2369·97	0·05	6	2370·1 „ 2369·9 T.&S.	0·75	13·4	42181·2
2363·28	0·05	1			13·5	42300·6
2356·68	0·05	4	2355·0 „ 2356·7 „			42419·1
2345·59	0·05	2	2346·2 „ 2346·2 „		13·6	42619·6
2319·70	0·05	4b		0·74	13·7	43095·3
2303·18	0·05	6	2303·8 „	0·73	13·9	43404·3
2294·44	0·05	2	2295·0 „ 2294·4 „			43569·7
2293·92	0·05	10r	2294·6 „ 2293·9 „			43579·6
††2288·19	0·05	4	2286·7 ? „ 2286·7 ? „			43688·8
2282·20	0·15	1b	2279·6 „ 2278·4 „		14·0	43803·4
2276·30	0·05	4	2277·0 „ 2276·3 „			43916·9
2263·20	0·05	6r	2263·2 „ 2263·2 „	0·72	14·1	44171·1
2260·58	0·05	4r				44222·3
‖2247·08	0·05	4b	2247·7 „ 2247·0 „		14·2	44488·0
2244·36	0·05	1	2244·0 „			44541·9
2242·68	0·05	4	2243·5 „ 2242·7 „			44575·3
2240·89	0·20	1b				44610·9
2238·52	0·05	2r				44658·2
2236·40	0·05	1r				44707·7
2230·16	0·05	8r	2230·0 „ 2230·1 „			44825·6
2228·95	0·05	4	2229·1 „ 2228·9 „			44850·0
2227·85	0·05	8r	2228·1 „ 2227·8 „			44872·1
2225·77	0·05	6r	2226·0 „ 2225·7 „			44914·1
2218·21	0·05	2	2218·5 „ 2218·2 „			45067·2
2215·78	0·03	6r	2215·8 „ 2215·7 „			45116·6
2214·68	0·03	8r	2214·1 „ 2214·4 „			45139·1
2210·35	0·05	2	2210·8 „ 2210·3 „			45227·5
2199·77	0 03	8r	2199·8 „ 2199·8 „			45444·9
2192·35	0·05	2b	2192·0 H. A. 2192·4 T.&S.	0·70	14·3	45598·9
2189·69	0·05	2	2189·6 „ 2189·9 „			45654·3
2181·80	0·05	4r	2181·0 „ 2181·8 „			45819·4
2179·41	0·10	4	2179·0 „ 2179·5 „			45869·7
2178·97	0·05	6r	2178·0 „			45878·9
2171·88	0·20	1r				46028·8
2169·49	0·05	1				46079·5
2165·20	0·05	4r				46170·8
2149·05	0·05	2	2148·8 „ 2149·2 „	0·69	14·4	46527·8
2136·05	0·05	2	2135·8 „ 2136·1 „			46801·0
2126·11	0·05	2	2124·4 „ 2126·2 „			47019·9
2123·06	0·05	2	2122·1 „ 2123·1 „			47087·4
2112·19	0·05	1	2110·5 „ 2112·2 „			47329·8
2104·88	0·05	4	2103·0 „ 2104·9 „		14·5	47494·1
2085·40	0·10	1	2085·5 „			47937·9
2068·45	0·10	1	2068·3 „			48320·9
2061·77	0·10	1	2062·7 ?		14·6	48487·4
2055·08	0·10	1	2055·1 „			48645·3
2043·73	0·10	1	2075·0 ?			48915·5
2037·28	0·10	1	2037·3 „			49070·5
2035·90	0·10	1	2036·0 „			49103·7

COPPER (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
2025·14	0·20	2r	2025·7 T. & S.			49364·7
2016·76	0·20	1	2016·9 ,,		14·7	49569·8
2015·53	0·20	1	2015·8 ,,			49600·0
2013·19	0·20	1	2013·2 ,,			49657·7
2009·31	0·20	1				49753·6
2003·50	0·20	1			14·8	49897·9
1999·68	0·20	1	1999·9 ,,			49993·2
1995·16	0·20	1				50106·5
1989·24	0·20	1	1989·4 ,,			50255·7
1979·26	0·20	1	1979·4 ,,			50509·1
1971·99	0·20	1	1970·4 ,,			50695·4
1956·83	0·20	1				51088·3
1943·88	0·20	1	1944·1 ,,			51428·7

The lines marked 4* 5* and 6* form a series of pairs, of which the oscillation frequency can be calculated from the formula $10^8\frac{1}{\lambda} = a - bn^{-2} - cn^{-4}$, where $a = 31591·6$ for the *first* line, and 31840·1 for the *second* line of the pair, $b = 131150$, $c = 1085060$. For those marked 4† and 5† the values are $a = 31591·6$ or 31840·1, $b = 124809$, $c = 440582$.

SILVER (ARC SPECTRUM).

Kayser and Runge (' Ueber die Spectren der Elemente,' Pt. VI. Berlin, 1892).

* See Iron. § See Bismuth. ‡ See Cadmium.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
5667·72	0·20	4n		1·67	5·2	17638·6
5545·86	0·20	4b^v		1·64	5·3	18026·2
5471·72	0·05	6 4*	5471·0 Thalén	1·62	5·4	18270·4
5465·66	0·05	10r	5465·2 ,,	,,	,,	18290·6
5436·0	0·50	2n		1·61	5·5	18390·4
5333·5	0·50	2b^v		1·58	5·6	18743·8
5329·93	0·20	4b^v		,,	,,	18756·4
5276·4	0·50	1b^v		1·56	,,	18946·7
*5209·25	0·05	10r 4*		1·54	5·7	19190·9
*5123·85	0·20	1b		1·52	5·8	19510·8
4993·2	0·50	1n		1·48	5·9	20021·3
4888·46	0·10	2b		1·45	6·1	20450·2
4874·36	0·15	4b^v	4875·0 ,,	,,	,,	20509·4
4848·33	0·25	4n		1·44	,,	20619·6
4797·0	0·50	2n		1·42	6·2	20840·2
4678·04	0·20	4b		1·39	6·3	21370·2
4668·70	0·10	8b^v 4†	4667·6 ,,	,,	6·4	21412·8
4616·03	0·20	4n		1·37	,,	21657·2
*4556·13	0·20	4n		1·36	6·5	21942·0
*4476·29	0·10	6b^v 4†	4475·9 ,,	1·33	6·6	22333·3

Silver (Arc Spectrum)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda+$	$\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4396·49	0·10	2b	4396·8 Lecoq de B.	1·31	6·8	22738·6
4379·45	0·15	4b		,,	,,	22827·1
4311·28	0·10	4b^{v}		1·29	6·9	23188·1
4212·1	1·00	8r 5*	4212·0 L. & D.	1·26	7·1	23734·0
4055·44	0·10	6r 5*	4053·9 ,,	1·22	7·4	24650·8
3991·9	1·00	1n		1·20	7·5	25043·2
‡3981·87	0·15	5b^{v} 5†		1·19	7·6	25106·2
3943·1	0·50	1b		1·18	,,	25353·2
3940·3	0·50	1b		,,	,,	25371·2
3914·47	0·20	2n		,,	7·7	25538·5
3907·63	0·20	2n		1·17	,,	25583·3
*3841·3	2·00	2b^{v} 5†		1·15	7·8	26025·1
3810·6	2·00	2n 6*		,,	7·9	26234·7
3710·1	1·00	1n 6†		1·12	8·1	26945·4
3681·8	0·50	2b^{r} 6*		1·11	8·2	27152·4
3624·0	0·50	1n 7*		1·10	8·4	27585·4
3557·3	0·50	1b		1·08	8·5	28102·7
3547·3	0·50	1b		1·07	8·6	28181·9
3542·67	0·15	4b	3542·2 H. & A.	,,	,,	28218·7
3505·43	0·20	1b 7*		1·06	8·7	28518·5
3501·90	0·10	4b		,,	,,	28547·2
3499·65	0·20	1b		,,	,,	28565·6
3383·00	0·03	10r	3383·5 ,,	1·03	9·0	29550·6
3327·82	0·05	1b		1·01	9·2	30040·5
3305·77	0·05	2b	3308·4 ,,	,,	,,	30240·9
3280·80	0·03	10r	3281·6 ,,	1·00	9·3	30471·1
3232·94	0·10	4b	3233·3 ,,	0·99	9·5	30922·1
3170·66	0·05	4b		0·97	9·7	31531·7
3130·09	0·05	6b	3129·4 ,,	0·96	9·8	31938·2
3099·19	0·05	2		0·95	9·9	32256·6
§2938·42	0·10	6b	2937·9 ,,	0·91	10·5	34021·4
*2824·50	0·10	8b		0·88	11·0	35393·5
2721·84	0·05	4	2721·3 ,,	0·85	11·5	36728·3
*2575·70	0·10	6b		0·81	12·2	38812·2
2447·94	0·05	2	2447·7 ,,	0·77	12·9	40837·8
2437·84	0·05	4	2437·7 ,,	,,	13·0	41006·9
2413·26	0·05	4	2413·7 ,,	0·76	13·2	41425·6
2375·1	1·00	10	2375·9 ,,	0·75	13·4	42090·1
*2331·41	0·05	4	2332·1 ,,	0·74	13·7	42878·8
2324·73	0·05	4	2325·8 ,,	,,	,,	43002·0
2320·31	0·05	4	2321·1 ,,	,,	,,	43084·0
2317·10	0·05	4	2317·9 ,,	,,	13·8	43143·6
2312·5	0·50	8n		,,	,,	43229·4
2309·74	0·10	10r	2310·5 ,,	,,	,,	43276·2
2248·79	0·05		2250·1 ,,	0·72	14·2	44454·2
2246·46	0·05		2247·8 ,,	,,	,,	44500·3

For the lines marked 4* 5* 6* 7* $a=30712{\cdot}4$ or $31633{\cdot}2$, $b=13062{\cdot}1$, $c=109382{\cdot}3$; for those marked 4† 5† 6† $a=30696{\cdot}2$ or $31617{\cdot}0$, $b=12378{\cdot}8$, $c=39430{\cdot}3$.

Gold (Arc Spectrum).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. V. Berlin, 1892).

† See Bismuth. * See Iron. ‡ See Tin.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda+$	$\frac{1}{\lambda}-$	
6278·37	0·05	4	6277·8 Thalén	1·85	4·6	15923·1
5957·24	0·05	4	5956·7 ,,	1·75	4·9	16781·4
5863·17	0·05	4	5863· Huggins	1·73	5·0	17050·6
5837·64	0·05	6	5837·7 Thalén	1·72	,,	17127·2
5656·00	0·05	4	5654·2 Huggins	1·67	5·2	17675·1
5230·47	0·05	4	5231·1 Thalén	1·55	5·7	19113·0
5064·75	0·05	2	5067·6 Huggins	1·50	5·8	19738·5
4792·79	0·05	6	4792·7 Thalén	1·42	6·2	20858·5
4488·46	0·05	4	4489·8 Huggins	1·34	6·6	22272·8
4437·44	0 05	4	4437·7 L. de B.	1·32	6·7	22528·8
4364·72	0·10	1		1·30	6·8	22904·2
4241·99	0·05	2		1·27	7·0	23566·8
4084·26	0·05	2		1·22	7·3	24476·9
4065·22	0·05	6	4064·6 ,,	,,	7·4	24591·5
4041·07	0·05	2		1·17	7·7	24738·2
3909·54	0·05	2		,,	,,	25570·8
3898·04	0·05	4b		,,	,,	25646·2
3553·72	0·03	2		1·08	8·6	28130·9
3467·19	0·10	1b		1·03	8·8	28833·0
3320·32	0·05	4b		1·01	9·2	30108·4
3308·42	0·05	2b		,,	,,	30216·7
*3265·18	0·05	2b				30617·0
3230·73	0·05	4b		1·00	9·4	30943·4
3204·81	0·05	4b		0·98	9·5	31193·6
3194·82	0·05	4b		0·97	9·6	31291·1
3181·90	0·10	1b		,,	,,	31418·2
3127·03	0·15	1b		0·96	9·8	31969·4
3122·88	0·03	6r	3122·8 L. & D.	,,	,,	32011·9
3117·08	0·05	4b		0·95	,,	32071·5
3038·25	0·05	1b		0·93	10·1	32903·6
3033·38	0·05	6n		,,	,,	32956·4
*3029·32	0·05	6		,,	,,	33000·6
†3024·67	0·15	2n		,,	,,	33051·4
*3014·32	0·10	2b		,,	10·2	33164·8
2975·73	0·10	1b		0·92	10·3	33594·9
2973·67	0·10	2n		0·91	,,	33618·2
*2970·55	0·10	2b		,,	10·4	33653·4
2963·89	0·05	4b		,,	,,	33729·0
2962·12	0·10	1n		,,	,,	33749·2
2932·33	0·05	6b		0·90	10·5	34092·1
‡2913·63	0·05	4		,,	10·6	34310·8
2905·98	0·05	6b		,,	10·7	34401·1
2892·07	0·05	4b		0·89	,,	34566·6
2883·55	0·05	4		,,	,,	34668·8
2748·35	0·05	4r		0·86	11·3	36374·2
2701·03	0·05	4		0·83	11·5	37011·4
2694·40	0·05	1b		,,	11·6	37102·4
2688·86	0·05	4		,,	,,	37188·9
2676·05	0·03	10r	2676·2 ,,	0·84	11·7	37315·0
2590·19	0·05	4		0·81	12·1	38595·1

GOLD (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2544·30	0·05	4		0·80	12·4	39291·1
2510·56	0·05	4		0·79	12·5	39819·3
2428·06	0·03	10r	2428·0 L. & D.	0·77	13·1	41172·0
2387·85	0·05	4		0·76	13·3	41865·4
2364·69	0·05	4		0·75	13·4	42275·4
2352·75	0·05	4		,,	13·5	42490·0
2283·42	0·05	4		0·73	14·0	43780·0

ALUMINIUM (ARC SPECTRUM).

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. VI. Berlin, 1892.)

§ See Silver. ‡ See Copper.

	Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångstrom)		Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3† {	3961·68	0·03	10r	3961·1 Th.	3960·9 H. & A.	1·19	7·6	25234·2
	3944·16	0·03	10r	3943·1 ,,	3943·2 ,,	1·18	,,	25346·3
	3092·95	0·03	6r }	3091·5 L.& D.	3091·9 ,,	0·95	9·9	32321·7
	3092·84	0·03	10r }			,,	,,	32322·8
	3082·27	0·03	10r	3080·5 ,,	3081·2 ,,	0·94	,,	32433·7
	3066·28	0·03	6		3065·0 ,,	,,	10·0	32602·8
	3064·42	0·03	6		3062·8 ,,	,,	,,	32622·6
	3060·04	0·03	6		3058·5 ,,	,,	,,	32669·3
	3057·26	0·03	6		3056·4 ,,	,,	,,	32699·0
	3054·81	0·03	6		3053·6 ,,	,,	,,	32725·3
	3050·19	0·03	6		3049·2 ,,	,,	,,	32774·8
4† {	2660·49	0·03	10r	2659·8 ,,		0·83	11·7	37575·4
	2652·56	0·03	10r	2652·0 ,,		,,	11·8	37687·6
	2575·49	0·03	4r }	2574·5 ,,		0·81	12·2	38815·4
	2575·20	0·03	10r }			,,	,,	38819·7
	2568·08	0·03	10r	2567·5 ,,		,,	,,	38927·4
	2426·22	0·20	4b^v			0·77	13·1	41203·3
	2419·64	0·20	2b^v			,,	,,	41315·3
6*† {	2378·52	0 05	6r	2378·4 ,,		0·75	13·3	42029·7
	2373·45	0·03	4r }	2373·3 H.&A. }	2373·2 L.&D.	,,	13·4	42119·4
	2373·23	0·03	8r }				,,	42123·3
	2372·21	0·05	4r	2372·0 ,, }			,,	42141·4
	2367·16	0·03	10r	2367·2 ,,	2366·9 ,,		,,	42231·3
	2321·64	0·03	4			0·74	13·7	43059·3
	2319·12	0·03	2			,,	,,	43106·1
	2317·55	0·03	2			,,	13·8	43135·2
	2315·05	0·03	2			,,	,,	43182·2
	2313·60	0·03	2			,,	,,	43208·9
§	2312·56	0·03	2			,,	,,	43228·3
7* {	2269·20	0·05	8	2268·7 L. & D.		0·72	14·1	44054·3
	2263·83	0·10	2r }	2263·1 ,,				44158·8
6† {	2263·52	0·05	8r }			,,		44164·9
	2258·27	0·10	2	2257·3 ,,				44267·6

Aluminium (Arc Spectrum)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}$−	
2231·27	0·20	1b^v			14·2	44803·4
‡ 2225·77	0·20	1b^v			14·3	44914·0
8* { 2210·15	0·10	4r	2210·0 L. & D.		14·4	45231·4
2204·73	0·10	4r	2205·0 ,,		14·5	45342·5
7† { 2199·71‡	0·20	1r			,,	45446·0
9* { 2174·13	0·10	1r	2175·0 Cornu		14·6	45980·8
2168·87	0·10	1r	2169·8 ,,		14·7	46092·3
10* { 2150·69	0·20	1r	2151·6 ,,		14·8	46481·9
2145·48	0·20	1r	2146·4 ,,		,,	46594·8
11* { 2134·81	0·20	1r	2134·6 ,,		14·9	46825·7
2129·52	0·20	1r	2129·4 ,,		15·0	46943·9
12* { 2123·44	0·20	1r	2122·5 ,,		,,	47078·4
2118·58	0·20	1r	2117·4 ,,		,,	47186·4

The oscillation frequencies (in air) of the pairs marked * can be calculated from the formula $10^8\frac{1}{\lambda}=a-bn^{-2}-cn^{-4}$, when $a=48308{\cdot}2$ for the *first* line, 48420·2 for the *second* line of the pair, $b=15666{\cdot}2$ and $c=250533{\cdot}1$; and for the pairs marked † $a=48244{\cdot}5$ for the *first* line and 48356·5 for the *second* line, $b=12752{\cdot}7$ and $c=68781{\cdot}9$. The figure preceding the sign * or † shows the value of n.

Indium (Arc Spectrum).

(Kayser and Rünge ('Ueber die Spectren der Elemente,' Pt. VI. Berlin, 1892.)

‡ See Zinc. ‖ See Cobalt. § See Iron. † See Thallium. ** See Copper.

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
				λ+	$\frac{1}{\lambda}$−	
4511·44	0·10	10r 3†	4510·2 H. & A.	1·34	6·6	22159·3
‡4101·87	0·10	8r 3†	4101·3 ,,	1·23	7·3	24371·8
3258·66	0·05	6r 4*	3257·8 ,,	1·00	9·4	30678·1
3256·17	0·05	10r	3255·5 ,,	0·99	,,	30701·5
3039·46	0·05	10r 4*	3038·7 ,,	0·93	10·1	32890·5
2932·71	0·05	6r 4†	2932·3 ,,	0·90	10·5	34087·7
2753·97	0·05	6r 4†	2752·8 ,,	0·86	11·3	36299·9
2720·10	0·20	2nr		0·85	11·5	36751·9
2714·05	0·05	6r 5*	2712·9 ,,	0·84	,,	36833 7
2710·38	0·05	10r	2709·3 ,,	,,	,,	36883·7
2666·33	0·20	2b^r		0·83	11·7	37493·0
2601·84	0·05	6r 5†	2602·5 ,,	0·82	12·1	38422·2
2572·71	0·20	2b^v		0·81	12·2	38857·3
2565·59	0·20	2n	2564·7 ,,	,,	,,	38965·2
2560·25	0·05	8r 5*	2559·5 ,,	0·80	,,	39046·5
2523·08	0·10	4r 6*		0·79	12·5	39621·6
‖2521·45	0·05	8r	2520·9 ,,	,,	,,	39647·2

INDIUM (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character		Previous Measurements (Ångström)	Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda +$	$\frac{1}{\lambda}-$	
2470·65	0·15	2		2470·2 H. & A.	0·78	12·8	40462·4
2468·09	0·05	4r	6†	2468·4 ,,			40504·4
2460·14	0·05	6r	5†	2460·8 ,,			40635·3
2430·8	0·50	1r	7*	2429·0 ,,	0·77	13·0	41125·7
2429·76	0·20	1r		2428·6 ,,	,,	,,	41143·3
§2399·33	0·15	4r?	7†		0·76	13·2	41665·1
2389·64	0·05	8r	6*	2388·0 ,,	,,	13·3	41834·0
†2379·74	0·20	1r	8*		0·75	13·3	42008·1
2357·7	0·50	1r	8†	2357·0 ,,	,,	13·5	42400·7
2340·30	0·15	6r	6†		0·74	13·6	42716·0
2306·8	0·50	1r	7*	2306·9 ,,	0·73	13·8	43336·3
2278·3	0·30	1r	7†		,,	14·0	43878·4
**2260·6	0·30	1r	8*		0·72	14·1	44221·9
2241·6	0·30	1r	8†			14·2	44596·8
2230·9	0·30	1r	9*			14·3	44811·6
**2218·3	0·30	1r	9†			14·4	45065·2
2211·2	0·30	1r	10*			,,	45209·9
2200·0	0·30	1r	10†			14·5	45440·1
2197·5	0·30	1r	11*			,,	45491·8
2187·5	0·30	1r	12*			14·6	45699 7
2180·0	0·30	1r	13*			,,	45857·0

The oscillation frequencies (in air) of the pairs marked * can be calculated from the formula $10^8\frac{1}{\lambda}=a-bn^{-2}-cn^{-4}$; where $a=44515{\cdot}4$ for the *first* line and 46728·6 for the *second* line of the pair, $b=13930{\cdot}8$, $c=131103{\cdot}2$, and for the pairs marked † $a=44535{\cdot}0$ for the *first* line, and 46748·2 for the *second* line of the pair, $b=12676{\cdot}6$, $c=64358{\cdot}4$. The figure preceding the sign * or † shows the value of n.

THALLIUM.

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. VI. Berlin, 1892).

|| See Indium.

Wave-length (Rowland)	Limit of Error	Intensity and Character		Previous Measurements (Ångström)		Reduction to Vacuum		Oscillation Frequency in Vacuo
						$\lambda +$	$\frac{1}{\lambda}-$	
5528·3	0·50	$2b^v$				1·63	5·3	18083·4
5350·65	0·03	10r	3†	5349·6 Thalén		1 58	5·6	18683·7
3775·87	0·03	10r	3†	3775·6 L. & D.		1·14	8·0	26476·0
3529·58	0·03	8r	4*	3528·3 ,,	3528·8 H.&A.	1·07	8·6	28323·4
3519·39	0·03	10r		3517·8 ,,	3518·6 ,,	,,	,,	28405·4
3229·88	0·03	10r	4†	3228·1 ,,	3229·0 ,,	0·99	9·5	30951·4
2978·05	0·20	$1b^v$				0·92	10·3	33568·7
2945·15	0·15	$4b^v$		2943·9 ,,		0·91	10·5	33943·6

THALLIUM—*continued.*

Wave-length (Rowland)	Limit of Error	Intensity and Character	Previous Measurements (Ångström)		Reduction to Vacuum		Oscillation Frequency in Vacuo
					$\lambda+$	$\frac{1}{\lambda}-$	
2921·63	0·03	6r 5*	2921·3 L.&D.	2920·8 H.&A.	0·90	10·6	34216·9
2918·43	0·03	10r	2917·8 ,,	2917·7 ,,	,,	,,	34254·4
2895·52	0·15	4b^{v}	2895·2 ,,	2893·9 ,,	,,	10·7	34525·4
2826·27	0·05	8r 5†	2825·8 ,,	2825·4 ,,	0·88	11·0	35371·3
2767·97	0·03	10r 4*		2767·1 ,,	0·86	11·2	36116·4
2710·77	0·03	4r 6*	2710·4 ,,	2709·4 ,,	0·84	11·5	36878·4
2709·33	0·03	8r	2708·8 ,,	2708·6 ,,	,,	,,	36898·9
2700·3	0·50	2n	2699·7 ,	2700·1 ,,	,,	,,	37021·4
2665·67	0·05	6r 6†	2665·0 ,,	2665·0 ,,	0·83	11·7	37502·3
2609·86	0·03	4r 7*	2609·4 } ,,	2608·7 ,,	0·82	12·0	38305·2
2609·08	0·03	6r	2608·6 }		,,	,,	38315·7
2585·68	0·05	4r 7†			0·81	12·1	38662·4
2580·23	0·03	8r 4†		2579·7 ,,	,,	12·2	38744·0
2553·07	0·10	2r 8* }	2552·0 ,,	2551·6 ,,	0·80	12·3	39156·2
2552·62	0·10	6r }			,,	,,	39163·1
2538·27	0·10	2r 8†				12·4	39384·5
2517·50	0·10	4r 9*	2517·0 ,,		0·79	12·5	39709·5
2508·03	0·15	1r 9†			,,	12·6	39859·3
2494·00	0·10	2r 10*			,,	,,	40083·6
2487·57	0·20	1r 10†			0·78	12·7	40187·2
2477·58	0·10	1r 11*		2477·6 ,,		,,	40349·3
2472·65	0·20	1r 11†				12·8	40429·6
2465·54	0·20	1r 12*				,,	40546·3
2462·01	0·30	1r 12†				,,	40604·4
2456·53	0·20	1r 13*				,,	40695·0
2453·87	0·30	1r 13†			0·77	12·9	40739·1
2449·57	0·30	1r 14*					40810·6
2447·59	0·30	1r 14†					40843·6
2444·00	0·30	1r 15*					40903·6
2442·24	0·30	1r 15†					40933·1
2439·58	0·30	1r 16*			,,	,,	40977·8
2416·78	0·15	1b^{v}			0·76	13·1	41364·3
‖2379·66	0·03	8r 5*	2380·0 ,,		0·75	13·3	42009·5
2362·16	0·15	2b^{r}	2364·8 ,,		,,	13·4	42320·7
2316·01	0·03	6r 4†			0·74	13·8	43163·9
2237·91	0·10	6r 6*	2238·7 Cornu		0·71	14·2	44670·3
2210·80	0·10	2r	2210·0 ,,			14·4	45218·1
2207·13	0·10	4r 6†				14·5	45293·2
2168·68	0·30	4r 7*	2169·0 ,,			14·7	46096·9
2152·08	0·30	1r 7†	2152·3 ,,			14·8	46451·9
2129·39	0·30	1r 8*	2128·6 ,,			15·0	46946·8

The lines marked * form a series of pairs for which in the formula $10^8\frac{1}{\lambda}=a-bn^{-2}-cn^{-4}$, $a=41542·7$ for the *first* line, 49337·6 for the *second*, $b=13229·3$, $c=126522·3$. For the pairs marked † $a=41506·4$ or 49301·3, $b=12261·7$, $c=79068·3$.

NITROGEN (VACUUM TUBE).

Ames ('Phil. Mag.' xxx. p. 57, 1890).
Eder and Valenta* ('Denkschr. Kais. Akad. Wissensch. Wien,' Bd. lx. 1893).

* Induction spark between moist carbons in air, which give also the following *ammonia* bands: 2594·7, 2593·4, 2586·8, 2585·3, 2478·0, 2476·6, 2470·7, 2469·5.
† See Hasselberg's 'Positive Band Spectrum of Nitrogen,' *Index*, p. 213.

Wave-length (Rowland)		Hasselberg † or Deslandres	Reduction to Vacuum		Oscillation Frequency in Vacuo (Ames)
Ames	Eder and Valenta		$\lambda +$	$\frac{1}{\lambda} -$	
4975·0		4974·0 H.	1·47	5·9	20094·6
4917·1		4916·72 ,,	1·46	6·0	20331·2
4813·9		4813·01 ,,	1·43	6·2	20767·0
4722·6		4721·61 ,,	1·40	6·3	21168·5
4666·35		4665·22 ,,	1·39	6·4	21423·6
4648·4		4647·30 ,,	1·38	,,	21506·4
4573·7		4572·78 ,,	1·36	6·5	21857·6
4489·6		4488·60 ,,	1·34	6·6	22267·1
4415·7		4414·68 ,,	1·32	6·7	22639·8
4356·3		4355·80 ,,	1·30	6·8	22948·5
4344·4		?	,,	6·9	23011·2
4269·15	4270	4268·83 ,,	1·28	7·0	23416·9
4200·85	4206	4200·26 ,,	1·26	7·1	23797·6
4141·2	4141	4140·24 ,,	1·24	7·2	24140·4
4094·0		4093·69 ,,	1·23	7·3	24418·7
4059·0	4058	4058·27 ,,	1·22	7·4	24629·2
3998·0	3997	3997·22 ,,	1·20	7·5	25005·0
3942·55	3942	3941·5 D.	1·18	7·6	25356·7
3894·25		3893·5 ,,	1·17	7·7	25671·2
3856·9		3856·2 ,,	1·16	7·8	25919·8
3804·85	3803	3804·2 ,,	1·14	7·9	26274·3
3755·15	3755	3754·45 ,,	1·13	8·0	26622·1
3710·15	3711	3709·3 ,,	1·12	8·1	26945·0
3671·35	3683	3670·5 ,,	1·11	8·2	27229·7
3642·0	3639	3640·9 ,,	1·10	8·3	27449·1
3576·85	3576	3576·0 ,,	1·08	8·5	27949·1
3536·5	3536	3536·4 ,,	1·07	8·6	28267·9
3500·15	3499	3499·1 ,,	1·06	8·7	28561·5
3469·05		3468·1 ,,	1·05	8·8	28817·3
3446·2		3445·3 ,,	,,	,,	29018·7
3371·2	3369	3370·8 ,,	1·03	9·1	29653·9
3338·6		3338·1 ,,	1·02	9·2	29948·5
3309·4		3308·7 ,,	1·01	,,	30207·8
3284·8		3284·2 ,,	1·00	9·3	30434·0
3267·5		3267·1 ,,	,,	9·4	30595·0
3158·9		3158·3 ,,	0·96	9·7	31646·9
3135·7		3134·9 ,,	,,	9·8	31881·0
3116·4		3115·75 ,,	0·95	,,	32078·5
3103·8		3103·2 ,,	,,	9·9	32208·7
2976·7	2976	2976·1 ,,	0·92	10·3	33583·9
2961·9	2962	2960·8 ,,	0·91	10·4	33751·7
2953·0	2953	2952·4 ,,	,,	,,	33853·4
2819·7		2818·7 ,,	0·87	11·0	35453·8
2814·15		2813·1 ,,	,,	,,	35523·7

This 'positive band' spectrum of nitrogen ('Index,' p. 112) consists of some seventy or eighty 'bands,' each most intense at the least refracted edge, which generally consists of three 'lines' forming a 'head' to the band. The measurements of Ames are of the *central* line of the head.

CARBON (LINE SPECTRUM).

Eder and Valenta ('Denkschr. Kais. Akad. Wissensch. Wien,' Bd. lx. 1893).

* Possibly not carbon lines.
† Due to cyanogen.
‡ Kayser and Runge (on Rowland's scale).

Wave-length (Rowland)	Intensity and Character	Previous Measurements (Ångström)		Reduction to Vacuum		Oscillation Frequency in Vacuo
				$\lambda +$	$\frac{1}{\lambda} -$	
6584·2	1	*6583·0 A. & Th.		1·93	4·5	15183
6578·7	1	*6577·5 ,,		,,	,,	15196
Not seen by	E. & V.	5694·1 5660·9 5646·5 5638·3				
5379·8	1	5379·0 A. & Th.		1·59	5·5	18583
5151·2	1	5150·5 ,,		1·53	5·8	19407
5144·9	1	5144·2 ,,		1·52	,,	19431
5133·7	1	5133·0 ,,		,,	,,	19473
4556·3	1	—		1·36	6·5	21941
4267·5	4	4266·3 H. & A.		1·27	7·0	23426
3920·8	2b	3919·5 ,,	3919·3 L. & D.	1·18	7·7	25497
†3883·8	3	3881·9 ,,		1·17	,,	25740
3877·0	1	3875·7 ,,	3876·5 ,,	1·16	,,	25785
†3872·0	2	3870·7 ,,	‡3871·5 K. & R.	,,	,,	25819
3861·6	1		3861·9 ,,	,,	7·8	25888
3854·5	1		3855·0 ,,	,,	,,	25936
3848·0	1		—	,,	,,	25980
†3590·1	1n	3589·9 ,,		1·09	8·5	27846
†3585·6	1n	3584·8 ,, 3583·3 ,,	3585·9 ,, 3584·1 ,,	1·08	,,	28873
†3361·0	n			1·02	9·1	29744
Not seen by	E. & V.	3167·7 ,, 3166·0 ,,				
2993·2	bn	2993·1 ,,	2995·0 L. & D.	0·92	10·3	33399
2967·6	bn	2967·3 ,,	2968·0 ,,	0·91	10·4	33687
2905·4	1					
2837·4	6	2836·7 ,,	2837·2 ,,	0·90	10·7	33408
2836·2	6	2835·9 ,,	2836·3 ,,	0·88	10·9	35248
2747·3	5	2746·6 ,,	2746·5 ,,	0·86	11·3	36388
Not seen by	E. & V.		2733·2 ,,			
2641·4	1	2640·0 ,,	2640·7 ,,	0·83	11·8	37847
2567·7	1			0·81	12·2	38933
2554·6	1			0·80	12·3	39133
2511·8	6	2511·6 ,,	2511·9 "	0·79	12·5	39800
2508·0	6	2508·7 ,,	2509·0 ,,	,,	12·6	39860
2498·0	1n			,,	,,	40020
2496·8	1n			,,	,,	40048
2479·0	10	2478·3 ,,	2478·3 ,,	0·78	12·7	40326
2402·1	1n			0·76	13·2	41617
2343·5	1n			0·74	13·6	42658
2342·6	1n			,,	,,	42674
2332·5	1n			,,	13·7	42859
2296·8	5b	2297·7 ,,	2296·5 ,,	0·73	13·9	43525

SILICON.

Eder and Valenta ('Denkschr. Kais. Akad. Wissensch. Wien,' Bd. lx. 1893).

* Characteristic group.

	Wave-length (Rowland)	Intensity and Character	Previous Measurements (Rowland)	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
			6366 Salet	1·87	4·6	1570–
			6341 „	1·86	„	1577–
			5981 „	1·76	4·9	1672–
			5960 „	„	„	1677–
			5057 „	1·50	5·9	1977–
			5041 „	1·49	„	1983–
			4566 „	1·36	6·5	2189–
	4131·5	4 }	4139 „	1·24	7·2	24197
	4126·5	4 }		„	„	24226
	3905·4	3	3901 „	1·17	7·7	25598
	3862·5	3		1·16	7·8	25882
	3855·7	3		„	„	25928
	3834·4	1		1·15	„	26072
	3826·7	1		„	7·9	26124
	3795·9	2		1·14	„	26336
	3791·1	1		„	„	26369
	3191·1	1		0·97	9·6	31327
	3086·8	1		0·94	9·9	32386
	2897·2	4		0·90	10·7	34505
	2881·6	10	2881·5 H. & A.	0·89	„	34692
	2689·8	1		0·84	11·6	37166
	2677·4	1		„	11·7	37338
	2673·3	1		0·83	„	37395
	2659·0	1		„	„	37596
	2631·9	8	2631·8 „	0·82	11·9	37983
	2568·8	2		0·81	12·2	38916
	2542·1	8	2541·5 „	0·80	12·4	39325
	2534·7	1		„	„	·39440
	2533·2	4		„	„	39463
*	2529·0	8	2528·6 „	„	„	39529
*	2524·1	8	2523·9 „	0·79	12·5	39606
*	2518·8	8	2518·9 „	„	„	39698
*	2516·0	10	2515·9 „	„	„	39743
*	2514·4	7	2514·0 „	„	„	39758
*	2506·7	8	2506·8 „	„	12·6	39881
	2479·8	1		0·78	12·7	40313
	2452·6	3		0·77	12·9	40760
	2446·0	3		„	„	40870
	2443·9	2		„	„	40905
	2439·4	2		„	„	40994
	2435·9	8	2435·8 „	0·77	13·0	41040
	2356·9	1		0·75	13·5	42415
	2303·3	1		0·73	13·9	43413
	2219·5	1			14·4	45041
	2218·7	1			„	45057
*	2217·2	4			„	45088
*	2212·3	3			„	45187
*	2211·5	3			„	45204
*	2208·5	3			14·5	45265
	2122·8	2			15·0	47093
	1929·0	1	1929·0 Von Schumann		16·2	51824

AMMONIA.

Eder (' Denkschr. Kais. Akad. Wissensch. Wien,' Bd. lx. 1893).
Lecoq de Boisbaudran, ' C. R.' ci. 43.
Magnanini, ' Atti della Reale Accademia dei Lincei ' (4), v. 1889, p. 900.
Dibbits, ' Pogg. Ann.' cxxii. 1864, p. 497.
Hofmann, ' Pogg. Ann.' cxlvii. 92.

* Double.

Flame Spectrum					Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Lecoq de Bois-baudran a	Dibbits b	Hofmann c	Magnanini d	Eder (Row-land) e		$\lambda+$	$\frac{1}{\lambda}-$	
	7330							
	6520		6666		1n	1·96	4·4	14998d
	6629	6630	6626		1n	1·95	4·5	15088d
		6590	6602		1s	1·94	„	15142d
	6542		6547		b_3	1·93	„	15270d
		6430	6433		b_5^v	1·89	„	15541d
			6405		1s	1·88	4·6	15608d
			6387		1s	„	„	15652d
			6366		1s	1·87	„	15703d
			6351		1s	1·86	„	15740d
6325	6330		6329		$6b^r$	„	„	15795d
6292	6290		6292		$6b^v$	1·85	„	15888d
			6262			1·84	4·7	15964d
	6227		6228			1·83	„	16052d
			6220			„	„	16072d
6180	6185		6188		$5b^v$	1·82	4·8	16155d
		6170	6170			„	„	16202d
	6130	6130						16308bc
	6117		6114		b	1·80	„	16351d
			6094					16405d
			6070			1·79	4·9	16469d
6045	6060	6060	6050		6	1·78	„	16524d
			6044		6	„	„	16540d
	6020	6030	6022		6	1·77	„	16601d
			6014		6	„	„	16623d
6008	5990	6010	6005		$6b^v$	„	„	16648d
	5970	5970	5972		5n	1·76	„	16740d
5964			5958		5n	1·75	„	16779d
			5922			1·74	5·0	16881d
			5912			„	„	16910d
		5890	5886		b^r	„	„	16984d
			5882			1·73	„	16996d
			5869		n	„	„	17034d
		585–	5860			„	„	17060d
		583	5832			1·72	5·1	17142d
	5807		5805		b	1·71	„	17221d
	5754		5787			„	„	17275d
			5773		s	1·70	„	17317d
			5762		b^r	„	„	17350d
		5740–	5746		b^r	„	„	17398d
		5710	5735			1·69	„	17432d
			5724		b^r	„	5·2	17465d
			5710			„	„	17508d

AMMONIA—*continued.*

Flame-spectrum					Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Lecoq de Bois-baudran a	Dibbits b	Hofmann c	Magnanini d	Eder (Row-land) e		$\lambda +$	$\frac{1}{\lambda} -$	
5702	5705		5702		6	1·68	5·2	17533d
			5693		6	,,	,,	17560d
	5664		5664		b_2	1·67	,,	17650d
			5640			1·66	,,	17725d
			5630			,,	,,	17757d
			5608			1·66	5·3	17827d
		5590	5597			1·65	,,	17862d
		5560	5568			1·64	,,	17954d
			5557			,,	,,	17990d
	5520		5525			1·63		18095d
			5485			1·62	5·4	18227d
			5465		b^v	1·61	,,	18293d
			5438			,,	,,	18384d
			5416			1·60	,,	18459d
	5390	5380	5390		n	1·59	5·5	18548d
			5339		b	1·58	5·6	18724d
			5303			1·57	,,	18851d
			5277		n b	1·56	,,	18970d
			5262		n	,,	,,	18998d
5252			5253		n b	1·55	,,	19031d
			5242		n	,,	,,	19071d
			5230		n	,,	5·7	19114d
			5212		b	1·54	,,	19180d
			5172			1·53	,,	19329d
			5166			,,	,,	19351d
	5158		5156		n	,,	5·8	19389d
	5128	5130	5127		b^r	1·52	,,	19499d
			5111		b	1·51	,,	19560d
	5079		5078	5079	b_1	1·50	,,	19683e
	4997			5007	b	1·48	5·9	19966e
		498?	4974	4984	b	,,	,,	20058e
				4966		1·47	6·0	20131e
				4924		1·46	,,	20303e
		4880	4878	4895		1·45	6·1	20423e
		4850	4864	4869		1·44	,,	20532e
			484?	4839		1·43	,,	20659e
	4782		4789	4785	b	1·42	6·2	20893e
			4774	4777		,,	,,	20928e
				4747		1·41	6·3	20060e
		4700 4690		4722	b	1·40	6·3	21171e
		4670 4650		4678		1·39	,,	21371e
				4662		,,	6·4	21444e
			4647?	4641		1·38	,,	21541e
		4610 4590		4620		1·37	,,	21639e
				4566		1·36	6·5	21895e
		4545	4538	4541	$b_{1·5}$	1·35	,,	22016e
			4513	4511		1·34	6·6	22161e
			4492	4499		,,	,,	22220e
				4488		,,	,,	22275e
				4460		1·33	6·7	22415e

AMMONIA—*continued.*

Flame Spectrum					Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
Lecoq de Boisbaudran a	Dibbits b	Hofmann c	Magnanini d	Eder (Rowland) e		$\lambda +$	$\frac{1}{\lambda} -$	
				4442	Bright lines on a weak continuous spectrum, but not so bright as the lines of the following bands: $\beta, \gamma, \delta, \epsilon, \zeta, \eta$.	1·32	6·7	22505
				4419		,,	,,	22623
				4350		1·30	6·9	22982
				4338		1·29	,,	23045
				4328		,,		23098
				4306		,,		23216
				4289		1·28	7·0	23308
				4244		1·27	,,	23556
				4204		1·26	7·1	23780
				4189		1·25	,,	23865
				4178		,,	,,	23928
				4162		,,	7·2	24020
				4142		1·24	,,	24136
				4099		1·23	7·3	24389
				4093		,,	,,	24425
				3959		1·19	7·6	25251
				3947		1·18	,,	25329
				3919		,,	,,	25509
				3885		1·17	,,	25732
				3797		1·14	7·9	26329
				3790		,,	,,	26377
				3779		,,	8·0	26454
				3750(?)		1·13	,,	26659
				3748		,,	,,	26673
				3740		,,	,,	26730
				3682		1·11	,,	27151
				3638		1·10	,,	27480
				3572		1·08	8·5	28088

Eder	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Eder	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$				$\lambda +$	$\frac{1}{\lambda} -$	
Band β					3370·0		1·02	9·1	29665
3432·2		1·04	8·9	29127	3359·4			,,	29758
3429·2			,,	29152	3353·5			,,	29810
3426·3			,,	29177	3340·3			,,	29928
3423·0			,,	29205	3336·0			9·2	29967
3419·6			,,	29234	3332·7			,,	29997
3416·0			,,	29265	3329·4		1·01	,,	30026
3412·6			,,	29294	3325·8			,,	30059
3408·9			,,	29326	3322·6			,,	30088
3405·5			9·0	29355	3318·9			,,	30122
3401·7			,,	29388	3315·9			,,	30148
3398·4		1·03	,,	29417	3312·8		1·01	,,	30177
3395·2			,,	29444	3209·6		,,		30208
3391·5			,,	29477	3306·5		,,		30234
3387·8			,,	29509	3303·8		,,		30259
3384·3			,,	29539	3300·8		,,	9·3	30286
3380·5			,,	29572	3298·3		,,	,,	30309
					3295·5		,,	,,	30335

AMMONIA—*continued.*

Eder	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
Band γ				
a 2718·3		0·85	11·5	36776
b 2717·2		,,		36791
c 2710·0		,,		36889
d 2708·2		0·84		36913
A shading of fine lines here which could not be measured.				
Band δ				
a 2594·7	2	0·81	12·1	38528
b 2593·4	3			38547
c 2586·8	2			38646
d 2585·3	4			38668
2583·0	3			38688
2581·8	3		12·2	38721
2580·5	3			38740
2579·6	3			38754
2578·6	3			38769
2577·3	3			38788
2576·3	3			38803
2575·1	3			38821
2573·6	3			38844
2572·4	3			38862
2571·2	3			38880
2569·9	3			38900
2568·3	3			38924
2567·0	3			38944
2565·3	3			38970
2563·7	3	0·80		38994
2562·2	3		12·3	39017
2560·6	3			39041
2558·9	3			39067
2557·3	2			39092
2555·4	2			39121
2553·7	1			39147
2551·7	1			39177
2549·9	1			39205
2549·0	1			39219
2548·0	1			39234
2547·0	1			39250
2546·0	1			39265
2545·1				39279
2543·9			12·4	39297
2543·1				39310
2542·3				39322
2541·5	nebulous			39334
2540·2				39355
2539·2				39370
2537·8				39392
2536·9				39406
2535·4				39429
2534·1				39449

Eder	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
2532·8				39470
2531·0				39498
2529·6				39519
2528·3				39540
2527·2	nebulous			39557
2526·2		0·79	12·5	39573
2525·1				39590
2523·6				39613
2522·7				39628
2521·5				39645
2500·4			12·6	39681
2499·1				40002
Band ε				
a 2478 0	2	0·78	12·7	40342
b 2476·6	3			40365
c 2470·7	3			40462
d 2469·5	5		12·8	40471
2463·4	3			40581
2462·2	3			40601
2461·3	3			40616
2460·3	4			40633
2459·4	4			40647
2458·4	4			40664
2457·4	4			40681
2456·4	4			40697
2455·4	3		12·9	40714
2454·3	3			40742
2453·1	3	0·77		40752
2451·9	3			40772
2450·7	3			40792
2449·7	3			40809
2447·7	3			40842
2446·8	3			40857
2445·0	3			40887
2443·8	3			40907
2442·5	3			40929
2441·5	3			40946
2439·5	2		13·0	40979
2437·9	2			41006
2436·4	2			41031
2434·5	2			41063
2432·7	2			41093
2431·8	2			41109
2429·9	2		13·1	41141
2428·1	2			41171
2427·1	2			41188
9424·8	2			41227
2423·0	2			41258
2421·1	1			41290
2419·2	1			41323
2418·8	1			41330
2416·9	1	0·78		41362
2414·5	1		13·2	41403

AMMONIA—*continued*.

Eder	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2413·0	1			41429
2410·8	1			41467
2409·3	1			41493
2407·8	1			41518
2406·3	1			41544
Band ζ				
a 2370·7	2	0·75	13·4	42168
b 2369·9	3			42182
c 2364·1	2			42286
d 2363·0	4			42306
2361·4	2		13·5	42334
2360·5	2			42351
2359·9	2			42361
2359·0	3			42377
2358·8				42381
2357·4	4			42406
2356·5	4			42422
2355·5	4			42440
2354·7	4			42455
2354·0	4			42467
2353·2	4			42482
2352·4	4			42496
2351·4	4			42514
2350·7	4			42527
2349·4	4			42551
2348·4	4		13·6	42569
2347·4	4			42587
2346·4	4			42505
2345·4	4			42523
2344·7	4	0·75		42636
2343·0	4	0·74		42667
2341·7	4			42690
2340·4	4			42714
2339·1	5			42723
2337·8	5			42761

Eder	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
2336·2	4			42791
*2334·8	3			42816
*2333·4	2		13·7	42843
2332·0	1			42868
2331·6	1			42875
2330·6	1			42894
2329·9	1			42907
2329·0	1			42923
2328·5	1			42932
2327·6	1			42949
2326·9	1			42962
2326·1	1			42977
2325·3	1			42992
2324·6	1			43004
2323·5	1			43021
2323·0	1			43034
2321·9	1			43054
2321·4	1			43064
2320·4	1			43082
2319·7	nebulous			43095
2317·9			13·8	43129
2316·5				43154
2315·1				43181
2313·1				43218
2311·6				43250
2309·4				43287
2307·4		0·73		43325
Band η				
a 2271	1	0·73	14·0	4402–
b 2270	1		14·1	4404–
c 2264	1			4416–
d 2262	1			4419–
A shading of fine lines extending to 2210				

CARBON.

Kayser and Runge ('Ueber die Spectren der Elemente,' Pt. II. Berlin, 1889).

s Strong. n Nebulous. * Double. d g Dark ground.

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
Second Carbon Band				
5635·43	1st edge	1·66	5·2	17739·6
5585·50	2nd edge	1·65	5·3	17898·2
5540·86	3rd edge	1·64	5·3	18042·4

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
Third Carbon Band				
5165·30	1st edge	1·53	5·7	19354·3
5165·12	s			19354·9
5164·84				19356·0

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ−	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum 1/λ−	Oscillation Frequency in Vacuo
5164·59				19356·9	5147·89	n			19419·5
5164·46				19357·4	5147·73	s			19420·1
5164·28				19358·1	5147·15				19422·4
5164·04				19359·0	5146·85				19423·6
5163·87				19359·6	5146·52				19424·8
5163·62				19360·6	5146·23	s			19425·9
5163·49				19361·0	5146·13				19426·3
*5163·16				19362·3	5145·52				19428·7
5162·96				19363·0	5145·27				19429·5
5162·60				19364·4	5144·98				19430·6
5162·41				19365·1	5144·72	s			19431·6
5161·95	n			19366·8	5144·62				19432·0
5161·77				19367·5	5143·91				19434·7
5161·40				19368·9	5143·64				19435·7
5161·23	n			19369·5	5143·37				19436·7
5161·08				19370·1	5142·98	s			19438·2
5160·79				19371·2	5142·89				19438·5
5160·43				19372·6	5142·15				19441·4
5160·31				19373·1	5141·93				19442·1
5159·92				19374·4	5141·69				19442·2
5159·66				19375·4	5141·37	s			19443·1
5159·50				19376·0	5141·26				19444·7
5159·10	n			19377·5	5140·41				19447·9
5158·69				19379·0	5140·18				19448·8
5158·58				19379·4	5139·95				19449·6
5158·17	n			19381·1	5139·49	s			19451·4
5157·79				19382·5	5139·39				19451·8
5157·65			5·7	19383·0	5138·56				19454·9
5157·24	n		5·8	19384·5	5138·34				19455·9
5156·71				19386·4	5138·13				19456·5
5156·61				19386·8	5137·72	s			19458·1
5156·17	n			19388·5	5137·62				19458·5
5155·70				19390·2	5136·71				19461·9
5155·56				19390·7	5136·47				19462·8
5155·25	n			19391·9	5136·31				19463·4
5155·07	n			19392·6	5135·70	s			19465·7
5154·49				19394·8	5135·63				19466·0
5154·35				19395·3	5134·70				19469·5
5153·82	n			19397·3	5134·53				19470·2
5153·32				19399·2	5134·34				19470·9
5153·21				19399·6	*5133·79	s			19473·0
5152·97				19400·5	5132·74				19477·0
5152·56	n			19402·0	5132·52				19477·8
5151·97				19404·3	5132·40				19478·5
5151·87				19404·6	*5131·68	s			19483·0
5151·57				19405·8	5130·62				19485·2
5151·22				19407·1	5130·46				19485·6
5150·73				19408·9	5130·32				19486·2
5150·61				19409·4	5129·67	s			19488·6
5150·20				19410·9	5129·36				19489·8
5149·83				19412·3	5129·20	s			19490·4
5149·33	n			19414·2	5128·93				19491·4
5149·14	s			19414·9	5128·72				19492·2
5148·65				19416·8	5128·51		1·52		19493·0
5148·36		1·52		19417·9	5128 23				19494·1

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
5128·02				19494·9	5106·60	s			19576·7
5127·73				19496·0	5106·44				19577·3
5127·38				19497·3	5106·00				19579·0
5127·26				19497·8	5105·44				19581·2
5127·03				19498·7	5105·11	n			19582·4
5126·88				19499·2	5104·67				19583·1
5126·73				19499·8	5103·95	s			19586·9
5126·30	s			19501·4	5103·80				19587·4
5126·13				19502·1	5103·43				19588·9
5126·04				19502·4	5103·17				19589·8
5125·71				19503·6	5102·93		1·52	5·8	19590·8
5125·53				19504·3	5102·53	s			19592·3
5125·30	n			19505·1	5101·58				19595·0
5124·90				19506·8	5101·10	s			19597·8
5124·82				19508·1	5100·95				19598·4
5124·11	s			19509·8	5099·89	s			19602·5
5123·87	s			19510·7	5099·27				19604·9
5123·34				19512·7	5098·34	s			19608·4
5123·21				19513·2	5098·19				19609·0
5122·88	s			19514·5	5097·80	n			19610·5
5122·46				19516·1	5097·51	n			19611·6
5122·36				19516·4	5097·36	n			19612·2
5121·76	s			19518·7	5096·84	s			19614·2
*5121·52				19519·7	5095·98	n			19617·5
5120·71				19523·7	5095·36	s			19619·9
5120·39				19525·0	5095·22				19620·4
5119·72	n			19526·5	5094·83				19621·9
5119·40	s			19527·7	5094·13	s			19624·6
*5119·21				19528·4	5093·74				19626·1
5118·85				19529·8	5093·45	n			19627·3
5118·17	s			19532·4	5092·88	n			19629·5
5118·08				19532·8	5092·52	s			19630·9
5117·38				19535·4	5092·36				19631·5
5116·93	s			19537·2	5091·85				19633·4
*5116·74				19537·9	5091·51				19634·8
5116·30				19539·6	5091·29	n			19635·6
5115·84	s			19541·3	5090·94	s			19636·9
5114·99				19544·6	5090·51	n			19638·6
5114·48	s			19546·5	5089·43	s			19642·7
5114·31				19547·2	5089·29				19643·3
5113·76				19549·3	5088·55				19646·2
5113·17	s			19551·6	5088·11				19647·9
5112·41				19554·5	5087·53				19650·1
5111·87	s			19556·5	5087·09				19651·8
5111·71				19557·1	5086·91				19652·5
5111·42				19558·2	5086·43	s			19654·4
5110·77	s			19560·7	5086·31				19654·8
5110·10	n			19563·3	5085·12				19659·4
5109·79				19564·5	5084·80	s			19660·7
5109·35	s			19566·2	5083·93	n			19664·0
5109·17				19566·9	5083·24	s			19666·7
5108·45	n			19569·6	5083·08				19667·3
5107·97	s			19571·4	5082·35	n			19670·1
5107·67				19572·6	5081·86	s			19672·0
*5106·98				19575·2	5081·42				19673·7

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
5080·45				19677·5	5050·86	s, n			19792·7
5080·15	s			19678·7	5049·89	s			19796·5
5080·03				19679·1	5049·68				19797·3
5078·44	s			19685·3	5049·52				19798·0
5078·16				19686·4	5048·61				19801·5
5077·70				19688·1	5048·46				19802·1
5077·52				19688·9	5048·27				19802·9
5076·83	s			19691·5	5047·68	n			19805·2
5076·70				19692·0	5047·41				19806·2
5075·42				19697·0	5047·16				19807·2
5075·03				19698·5	5047·02				19807·8
5073·64				19703·9	5045·39	s			19814·2
5073·53				19704·3	5044·87		1·49		19816·2
5073·16				19705·8	5043·81	n			19820·4
5072·61				19707·9	5043·42	n			19821·9
5072·48	n			19708·4	5041·47	s			19829·6
5071·88	s			19710·8	5040·86	n			19832·0
*5070·46				19716·3	5040·54				19833·2
5070·20	s			19717·3	5039·88	s			19835·8
5070·08				19717·8	5038·60	n			19840·9
5069·86				19718·6	5038·22				19842·4
5068·73	s			19723·0	5037·82	s			19844·0
5068·28				19724·8	5037·57				19844·9
5067·91				19726·2	5037·42				19845·5
5067·59	n			19727·4	5035·79	n			19852·0
5066·91	s			19730·1	5035·14	n			19854·5
5066·81				19730·5	5034·46				19857·2
5066·46				19731·9	5034·27				19858·0
5066·32	s			19732·4	5033·84	s			19859·7
5066·07				19733·4	*5033·68				19860·3
5065·56				19734·4	5033·08				19862·7
5065·41				19735·9	5032·18	s			19866·2
5065·18				19736·8	*5031·91				19867·3
5065·09	s			19737·2	5030·48				19872·9
5064·59	n	1·50		19739·2	5030·05	s			19874·6
5064·32				19740·2	5029·60				19876·4
5063·67	s			19742·7	5028·54	n			19880·0
5063·39			5·8	19743·8	5027·94				19883·1
5062·46			5·9	19747·4	5027·65				19884·0
5061·81				19749·9	*5025·92	s			19891·0
5061·53				19751·0	5025·49	n			19892·7
5059·94				19757·2	5024·22	s			19897·7
5059·85				19757·5	5024·09				19898·2
5059·34	n			19759·5	5022·07	s			19906·3
5058·91				19761·2	5021·72				19907·6
5058·06	s			19764·5	5020·89				19910·9
5056·80				19769·5	5020·79				19911·3
5056·30	s			19771·4	5019·87				19914·9
5056·21				19771·8	5018·58	n			19920·1
5055·88	n			19773·0	*5017·83	s			19923·0
5054·73	s			19777·5	5017·28				19925·2
5054·37				19779·0	5017·13				19925·7
5053·66				19781·7	5016·12				19929·8
5053·14				19783·8	5015·29	n			19933·1
5052·75	s			19785·3	5014·84	n			19934·9

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
5013·89	s			19938·7	4957·42				20165·8
5012·42	n			19944·5	4956·08	s			20171·2
5011·66				19947·6	4954·70				20176·9
5010·03				19954·1	4954·25				20178·7
5009·62 }	s			19955·7	4951·50	s			20189·9
5009·53 }				19956·1	4950·69				20193·2
5009·18				19957·4	4950·20				20195·2
5007·82				19962·9	4949·14				20199·5
5007·27	n			19965·1	4946·46	s			20210·5
5006·50	n			19968·1	4946·08				20212·0
5006·24				19969·2	4944·69				20217·7
*5005·55	s			19971·9	4942·94				20224·9
5004·37				19976·6	4942·62				20226·2
5003·20				19981·3	4941·92		1·46		20229·1
*5002·68				19983·4	4940·90				20233·2
*5001·09	s			19989·7	4937·37				20247·7
5000·32				19992·8	4936·83				20249·9
4999·91				19994·5	4935·11				20257·0
4999·65				19995·5	4933·27				20264·5
4999·32				19996·8	4932·18				20269·0
4999·09	n			19997·7	4928·52				20284·1
*4996·99	s			20006·1	4926·96				20290·5
4995·16	n			20013·5	4924·87				20299·1
4994·68	n			20015·4	4924·28				20311·6
4993·39				20020·6	4918·05				20327·3
4992·89				20022·6	4916·96				20331·8
*4992·44	s			20024·4	4915·16				20339·3
4991·50				20028·2	4914·63				20341·5
4991·12				20029·7	4912·23				20351·4
4990·64				20031·6	4906·86		1·45		20373·6
4990·12	n			20033·7	4905·88				20377·7
4988·27	s			20041·1	4905·42				20379·6
4987·44				20044·5	4901·96				20394·0
4986·70	n			20047·5	4900·90				20398·4
4985·96				20050·4	4899·98				20402·1
4983·62	s			20059·8	4897·56				20412·1
4981·79				20067·2	4896·52			6·0	20416·6
4979·36	s			20076·0	4893·72			6·1	20428·2
4976·97				20086·7	4890·89				20440·1
4975·69	n			20091·8	4887·01				20456·3
4974·58	s			20096·2	4886·14	s			20460·0
4973·69				20099·9	4885·64				20462·0
4972·78				20103·6	4885·05				20464·5
4971·54				20108·6	4881·19				20480·7
4970·25	s		6·0	20113·7	4877·33				20496·9
4967·84				20123·4	4875·51				20504·6
4967·53				20124·7	4870·58				20525·3
4965·39	s			20133·4	4867·52				20538·2
4963·60				20140·7	4864·86				20549·5
4963·02				20143·0	4859·88				20570·5
4960·96	s			20151·4	4858·55				20576·2
4959·19				20158·6	4857·68				20579·9
4958·59				20161·0	4855·95				20587·2
4958·16				20162·6	4854·11	s			20595·0
4957·73				20164·5	4853·67				20606·9

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4852·44				20612·1
4848·93	s			20617·0
4847·66				20622·4
4843·11				20641·8
4842·31				20655·2
4837·99	s			20663·6
4837·59				20665·4
4832·80				20685·9
4832·13				20688·7
4827·38				20709·1
4826·87				20711·3
4825·88				20715·5
4821·80			6·2	20732·9
4820·93				20736·7
4817·14				20753·0
4815·66				20759·4
4811·99				20775·2
4811·50				20777·3
4809·63	s			20785·4
4804·35	s			20808·6
4801·03				20822·6
4798·79				20832·4
4798·32	s			20834·4
4796·24				20843·5
4792·92				20857·9
4786·88				20884·2
4785·63				20889·7
4781·46				20907·9
4779·44				20916·8
4775·32				20934·8
4772·18				20948·6
4769·87				20958·7
4763·86				20985·2
4758·33				21009·6
4752·06				21037·3
4746·55				21061·7
Fourth Carbon Band				
4737·18			6·3	21103·3
4737·01				21104·2
4736·33				21107·2
4736·13				21108·0
4735·81				21109·4
4735·44				21111·1
4735·04				21112·8
4734·59				21114·9
4734·06				21117·2
4733·54				21119·5
4732·96				21122·1
4732·33				21124·9
4731·93				21126·7
4730·92				21131·2
4729·99				21135·4
4729·33				21138·3

Wave-length	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4728·37				21142·7
4727·61				21146·0
4727·09				21148·4
4726·43				21151·3
4726·11				21152·7
4725·62				21154·9
4725·05	n			21157·5
4724·47				21160·1
4723·97	n			21161·9
4723·50				21164·4
4722·23				21170·2
4721·19				21174·8
4719·87				21180·7
4718·76				21185·7
4717·30				21192·3
4716·70	n			21195·0
4716·10				21197·7
4715·31				21201·2
4715·14	s			21202·0
4714·57				21204·5
4714·04	n			21206·9
4713·45				21209·6
4713·21	s			21210·6
4712·69				21213·0
4712·22				21215·1
4711·67	s			21217·6
4711·11				21220·1
4710·40	s			21223·3
4709·85				21225·8
4709·12				21229·1
4708·58	s			21231·5
4707·60				21235·9
4707·18				21237·8
4706·87				21239·2
4705·88				21243·7
4705·39				21245·9
4705·15				21247·0
4703·96				21252·4
5703·64				21253·8
4703·16				21256·0
4702·53				21258·8
4702·03	s			21261·1
4701·46				21263·7
4701·05				21265·5
4700·39				21268·5
4700·16		1·40	6·3	21269·6
4699·84				21271·0
4699·35				21273·2
4698·84				21275·5
4698·37	n			21277·7
4697·57	s			21281·3
4697·14				21283·3
4696·74				21285·1
4696·41				21285·6
4695·95				21287·6

CARBON—*continued.*

Wave-length	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
4695·58				21290·3	4688·24				21323·7
4695·22		1·39		21292·0	4687·93				21325·1
4694·55				21295·0	4687·34				21327·8
4694·20				21296·6	4686·92				21329·7
4693·83	s			21298·3	4686·56				21331·3
4693·23				21301·0	4686·14				21333·2
4692·97				21302·2	4685·87				21334·5
4692·70				21303·5	4685·47				21336·3
4691·97				21306·7	4684·94				21338·7
4691·12				21310·6					
4690·66	s			21312·7	Fifth Car	bon Band			
4690·18				21315·1					
4689·43				21318·3	4381·93		1·31	6·8	22814·2
4688·98				21320·3	4371·31				22869·6
4688·68				21321·7	4365·01				22892·7

CYANOGEN (ARC SPECTRUM).

Kayser and Runge, 'Ueber die Spectren der Elemente,' pt. ii. Berlin, 1889.

* Eder and Valenta observed (*Denkschr. Kais. Akad. Wissensch. Wien*, lx. 1893) in the spark-spectrum between carbon-electrodes in air the 'edges' 4216, 4197, 4181, 4167, 4157 of the second band; 3883·8, 3872·0, 3861·6, 3854·5 of the third band; 3590·1, 3585·6, 3584 of the fourth band; and 3361·0.

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum λ+	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
Second Band	of the	Cyanogen	Spectrum		4212·05	8			23734·3
					4211·85				23735·4
*4216·12	1st edge	1·26	7·1	23711·4	4211·51	8			23737·4
4215·96				23712·5	4211·32				23738·4
4215·78				23713·5	4210·98				23740·3
4215·62	8			23714·3	4210·77				23741·5
4215·47				23715·1	4210·37				23743·2
4215·26	8			23716·3	4210·18	8			23744·8
4214·99	8			23717·7	4209·83				23746·8
4214·71	8, n			23719·3	4209·57	8			23748·3
4214·40	d			23721·1	4209·20				23750·4
4214·15	8			23722·5	4208·93	8			23751·9
4214·03				23723·2	4208·51				23754·3
4213·77	8			23724·6	4208·24	8			23755·8
4213·66				23725·2	4207·89	d			23757·8
4213·37	8			23726·9	4207·54	8			23759·8
4213·24				23727·6	4207·09				23762·3
4212·97	8			23729·1	4206·80	8			23763·9
4212·80				23730·1	4206·54				23765·4
4212·52	8			23731·7	4206·32				23766·7
4212·34				23732·7	4206·03	8			23768·3

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4205·78				23769·7
4205·53				23771·1
4205·25	8			23772·7
4204·99				23774·2
4204·71				23776·8
4204·41	8			23777·4
4204·10				23779·2
4203·86				23780·6
4203·56	8			23782·3
4203·29				23783·8
4203·01				23785·4
4202·65	8			23787·4
4202·38				23788·9
4202·12	8			23789·4
4201·73				23792·6
4201·47				23794·1
4201·15				23795·9
4200·80	8			23797·9
4200·47				23799·8
4200·22				23801·2
4199·82	8			23803·4
4199·48				23805·4
4199·21				23806·9
4198·81	8			23809·2
4198·43				23811·4
4198·19				23812·8
4197·77	8			23814·1
4197·50				23816·6
*4197·24	2nd edge	1·25	7·1	23818·1
4197·02				23819·3
4196·89				23820·1
4196·69				23821·2
4196·50				23822·3
4196·28				23823·5
4196·05	8			23824·8
4195·77 }	d g			23826·4
4195·46 }				23828·2
4195·14				23830·0
4195·03				23830·6
4194·77				23832·1
4194·61				23833·0
4194·37				23834·4
4193·97				23836·7
4193·82				23837·5
4193·51				23839·3
4193·31				23840·4
4193·03	8			23842·0
4192·67				23844·0
4192·51				23845·0
4192·15				23847·0
4191·95				23848·1
4191·46	8			23850·9
4190·86	n			23854·1
4190·54				23856·0
4190·25	8			23857·8
4189·63	8			23861·3
4189·02	8			23862·8
4188·50	n			23867·8
4188·14				23869·9
4187·74				23872·1
4187·40				23874·1
4187·11				23875·7
4186·65				23878·3
4186·41				23879·7
4185·84	8			23883·0
4185·04	8			23887·5
4184·45				23890·9
4184·17				23892·5
4183·73				23895·0
4183·33				23897·3
4183·04				23899·0
4182·39	8			23902·7
4181·89				23905·5
4181·47	8			23907·9
4180·98 }				23910·7
4180·49 }				23913·5
4180·31				23914·6
4180·11				23915·7
4179·89				23917·0
4179·58				23918·7
4179·33				23920·2
4179·01				23922·0
4178·70				23923·8
4178·48				23925·0
4178·29				23926·1
4177·96	8			23928·0
4177·48	8			23930·8
4177·05				23933·2
4176·51				23936·3
4176·43				23936·8
4176·05				23939·0
4175·75				23940·7
4175·54				23941·9
4175·28				23942·4
4174·99	8			23945·1
4174·42				23948·4
4174·13				23950·2
4173·80				23951·9
4173·41				23954·1
4173·14				23955·7
4172·98				23956·6
4172·53				23959·2
4172·18				23961·2
4171·82	8			23963·3
4171·09				23967·5
4170·63				23970·1
4170·22				23972·5
4169·59	n			23976·1
4169·31				23977·7
4168·83				23980·4

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4168·55				23982·1	4151·73				24079·2
4168·20				23984·1	4151·50				24080·5
4168·09				23984·7	4151·15				24082·5
4167·77				23986·5	4150·82				24084·4
4166·90				23991·6	4150·47				24086·5
4166·71				23992·7	4150·17				24088·2
4166·42				23994·3	4149·89				24089·8
4166·14				23995·9	4149·61				24091·5
4165·85				23997·6	4149·26	8			24093·5
4165·49	8			23999·7	4148·81				24096·1
4165·19	8			24001·4	4148·58				24097·4
4164·81				24003·6	4148·21				24099·6
4164·37				24006·1	4148·00				24100·8
4164·11				24007·6	4147·65				24102·8
4163·92			7·2	24008·5	4147·28				24105·0
4163·49	8, n			24011·1	4146·86				24107·4
4163·06				24013·6	4146·69				24108·4
4162·76				24015·3	4146·41				24110·1
4162·54				24016·6	4146·16				24111·5
4162·39				24017·5	4146·01	8			24112·4
4162·07				24019·3	4145·62				24114·6
4161·75	8			24021·2	4145·37				24116·1
4161·38	8			24023·3	4145·16				24117·3
4160·89				24026·1	4144·88				24118·9
4160·38				24029·1	4144·72				24119·3
4159·96	8			24031·5	4144·31				24122·3
4159·71				24032·9	4144·03				24123·9
4159·47				24034·3	4143·72				24125·6
4159·29				24035·4	4143·51				24126·9
4159·01				24037·0	4143·07	8			24129·5
4158·74				24038·5	4142·91				24130·4
4158·50		1·24		24039·9	4142·60				24132·2
4158·17	s, n			24041·8	4142·19				24134·6
4157·89				24043·5	4141·95				24136·0
4157·55				24045·4	4141·70				24137·5
4157·32				24046·8	4141·39				24139·3
4157·02				24047·5	4141·15				24140·7
4156·63				24050·8	4140·89	8			24142·2
4156·35				24052·4	4140·71				24143·3
4156·06				24054·1	4140·29	8			24145·7
4155·90				24055·0	4139·96				24147·6
4155·78				24055·7	4139·79				24148·6
4155·53	n			24057·1	4139·56				24150·0
4155·39				24057·9	4139·30				34151·5
4155·02				24060·1	4139·14				24152·4
4154·74				24061·7	4138·83				24154·2
4154·53				24062·9	4138·66				24155·2
4154·24				24064·6	4138·39				24156·8
4153·98				24066·1	4138·11				24158·4
4153·59			7·2	24068·4	4137.75				24160·5
4153·34				24069·8	4137·39	8			24162·6
4152·88				24071·5	4137·18				24163·9
4152·67				24073·7	4136·95				24165·2
4152·40				24075·3	4136·73				24166·5
4152·02				24077·5	4136·46				24168·1

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
4136·17				24169·8	4117·32				24280·3
*4135·87				24171·5	4116·98				24282·3
4135·53				24173·5	4116·68				24284·1
4135·10				24176·0	4116·57				24284·8
4134·94				24177·5	4116·29				24286·4
4134·70				24178·4	4115·93				24288·5
4134·27				24180·9	4115·53				24290·9
4133·76	8			24183·9	4115·38				24291·8
4133·39	8			24186·0	4114·81				24295·2
4132·73				24189·9	4114·67				24296·0
4132·51				24191·2	4114·30				24298·2
4132·31		1·24	7·2	24192·3	4114·15	8			24299·1
4132·11				24193·5	4113·73				24301·5
4131·88				24194·9	4113·25				24304·4
4131·55				24196·8	4113·08				24305·4
4131·19	8			24198·9	4112·65				24307·9
4130·76				24201·4	4112·33				24309·8
4130·40				24203·6	4112·14				24310·8
4130·20				24204·7	4111·88				24312·5
4129·61				24208·2	4111·57				24314·3
4129·43				24209·2	4111·03				24317·5
4129·04				24211·5	4110·83				24318·7
4128·74				24213·3	4110·46				24320·9
4128·14	8			24216·8	4109·99	8			24323·7
4127·91				24218·1	4109·55				24326·3
4127·51				24220·5	4109·29				24327·8
4127·15				24222·6	4108·90				24330·1
4126·91				24224·0	4108·60				24331·9
4126·67	8			24225·4	4108·39				24333·1
4126·17				24228·4	4108·16				24334·5
4125·97				24229·5	4107·89				24336·1
4125·54				24232·1	4107·59				24337·7
4125·25				24233·8	4107·30				24339·6
4125·01		1·23		24235·2	4107·05				24341·1
4124·62				24237·5	4106·73	8			24343·0
4124·25	8			24239·6	4106·28				24345·6
4123·80				24242·3	4105·78				24348·6
4123·40				24244·6	4105·45				24350·5
4123·09				24246·5	4105·13				24352·4
4122·89				24248·2	4104·80				24354·4
4122·30	8, n			24251·1	4104·58				24355·7
4121·86				24253·7	4104·16				24358·2
4121·53				24255·6	4103·86				24360·0
4121·19				24257·6	4103·61				24361·5
4120·89				24259·4	4103·33				24363·2
4120·60				24261·1	*4102·84	8			24366·1
4120·30				24262·9	4102·26	n			24369·5
4120·11				24264·0	4101·65				24373·1
4119·43	8			24268·0	4101·38				24374·7
4119·09				24270·0	4100·94				24377·4
4118·65				24272·6	4100·64				24379·1
4118·31				24274·6	4100·32				24381·0
4118·00			7·3	24276·7	4099·96				24383·2
4117·84				24277·3	4099·58				24385·4
4117·66				24278·3	4099·22	8			24387·6

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4098·95				24389·2	4079·12				24507·8
4098·65				24391·0	4078·71				24509·3
4098·38				24392·6	4078·43				24511·9
4098·15				24394·0	4078·15				24512·6
4097·82				24395·9	4077·84	8			24515·5
4097·61				24396·2	4077·63				24516·7
4097·29				24398·1	4077·31				24518·7
4096·99	8			24400·9	4076·97				24520·7
4096·65				24402·9	4076·62				24522·8
4096·02	n			24406·6	4076·30				24524·8
4095·58				24409·3	4076·01	8			24526·5
4095·34				24410·7	4075·66				24528·6
4094·98				24412·8	4075·25				24531·1
4094·71				24414·5	4074·65				24534·7
4094·39	n			24416·4	4074·24				24537·2
4093·88				24419·3	4073·92				24539·1
4093·55				24420·9	4073·69	8		7·4	24540·4
4092·93	8			24425·0	4073·28				24542·8
4092·47				24427·3	4073·10				24543·9
4091·97				24430·8	4072·49				24547·6
4091·61				24433·0	4071·98				24550·7
4091·25				24435·1	4071·61				24552·9
4090·90	8			24437·2	4071·13				24555·8
4090·20	8, n	1·22		24441·4	4070·70				24557·4
4089·60				24445·0	4070·37				24560·4
4089·30				24446·8	4070·04				24562·4
4088·88	n			24449·3	4069·71				24564·4
4088·34				24452·5	4069·33	8			24566·7
4087·88	8, n			24455·3	4069·00				24568·7
4087·14				24459·7	4068·67				24570·7
4086·80				24461·3	4068·27				24572·1
4086·58				24463·0	4068·05				24574·4
4086·30				24464·7	4067·68				24576·6
4085·85				24467·4	4067·49				24577·8
4085·54				24469·3	4067·17				24579·7
4085·20				24471·3	4066·83				24581·8
4084·86				24473·3	4066·56				24582·4
4084·61				24474·8	4066·22				24585·5
4084·51				24475·4	4065·66				24588·9
4084·07				24478·1	4065·20				24591·6
4083·94				24478·9	4064·85				24593·8
4083·70				24480·3	4064·44				24596·2
4083·43				24481·9	4064·10				24598·3
4083·26	8			24482·9	*4063·15				24604·1
4082·89				24485·2	4062·63				24607·2
4082·59		1·22	7·3	24487·0	4062·26				24609·4
4082·29				24488·8	4062·01				24611·0
4081·94				24490·9	4061·53				24614·3
4081·48				24492·6	4061·15				24616·4
4081·19				24495·4	4060·73				24618·7
4080·84				24497·5	4060·34				24621·1
4080·54				24499·3	4059·92				24623·6
4080·33				24500·5	4059·48				24626·3
4079·96				24502·7	4059·11				24628·5
4079·52				24505·4	4058·67				24631·2

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4058·31				24633·4	4037·25				24761·9
4058·04				24635·0	4036·85				24764·4
4057·68				24637·2	4036·60				24765·9
4057·33				24639·4	4035·83				24770·7
4057·15				24640·5	4035·49				24772·7
4056·83				24642·4	4035·17				24774·7
4056·55				24644·1	4034·98				24775·9
4056·12		1·22	7·4	24646·7	4034·56	8			24778·5
4055·75				24648·9	4034·20				24780·7
4055·42		1·21		24651·0	4033·70				24783·7
4054·92				24653·6	4033·15				24787·1
4054·56				24656·5	4032·50				24791·1
4054·14				24658·7	4031·76				24795·7
4053·87				24660·4	4031·50				24797·3
4053·58				24662·2	4031·16				24799·4
4053·35	8			24663·6	4030·88				24801·1
4053·00				24665·7	4030·57				24803·0
4052·70				24667·5	4029·75	n		7·5	24807·9
4052·38				24669·5	4029·30				24810·9
4052·09				24671·2	4028·85				24813·7
4051·66				24673·8	4028·41				24816·4
4051·00	8			24677·9	4028·09				24818·4
4050·61				24680·2	4027·74				24820·5
4050·31				24682·1	4027·01				24825·0
4050·16				24683·0	4026·64		1·21	7·5	24827·1
4049·87				24684·8	4025·13				24836·4
4049·62				24686·3	4024·88				24838·0
4049·14				24689·2	4024·64				24839·4
4048·74				24691·6	4024·34				24841·3
4048·37				24693·9	4023·92				24844·0
4047·74				24697·7	4023·69				24845·4
4047·31				24700·4	4023·14	n			24848·7
4047·03				24702·1	4022·67				24851·6
4046·68				24703·2	4021·90				24856·4
4046·33				24706·4	4021·57				24858·4
4045·73				24710·0	4021·14				24861·1
4045·35				24712·3	4020·71				24863·7
4044·93				24714·9	4020·43				24865·5
4044·63				24716·7	4019·73		1·20		24869·6
4044·48				24717·7	4019·32				24872·3
4044·22				24719·2	4018·83				24875·4
4043·94				24721·6	4018·53				24877·2
4043·65				24722·7	4018·19				24879·3
4043·43				24724·1	4017·80				24881·7
4042·53	n			24729·6	4017·57				24883·2
4042·14				24732·0	4017·26				24885·1
4041·53				24735·7	4016·81	n			24887·9
4041·28				24737·2	4016·08				24892·4
4040·55	n			24741·7	4015·45				24896·3
4040·28				24743·4	4014·94				24899·5
4039·40	n			24748·8	4014·64				24901·3
4038·79				24752·5	4014·32				24903·3
4038·40				24754·9	4013·80				24906·6
4038·09				24756·8	4013·56				24908·0
4037·81				24758·5	4013·28				24909·8

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
4012·97				24911·7
4012·72				24913·2
4011·82				24918·8
4011·60				24920·2
4011·32				24922·0
4010·47				24927·2
4009·68				24932·2
4009·44				24933·6
4009·18				24935·3
4008·94				24936·8
4008·57				24939·1
4008·12				24941·9
4007·73				24943·3
4007·50				24945·7
4006·72	n			24950·6
4005·51				24958·1

Third band of the Cyanogen Spectrum

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3883·55	1st edge	1·17	7·7	25741·9
3883·16				25744·5
3883·01				25745·5
3882·85				25746·6
3882·67				25747·8
3882·50				25748·9
3882·27				25750·4
3882·05				25751·9
3881·79				25753·6
3881·51				25755·4
3881·21				25757·5
3880·89		1·17	7·7	25759·6
3880·58	8			25761·6
3880·49				25762·2
3880·21	8			25764·1
3880·14				25764·6
3879·85	8			25766·5
3879·74				25767·2
3879·45	8			25769·1
3879·36				25769·7
3879·03	8			25771·9
3878·91				25772·7
3878·60				25774·8
3878·46				25775·7
3878·13				25777·9
3878·00				25778·8
3877·65				25781·1
3877·50		1·16		25782·1
3877·14				25784·5
3876·99				25785·5
3876·83				25786·6
3876·62				25788·0
3876·48				25788·9
3876·07	8			25791·6
3875·90				25792·7
3875·77				25793·6
3875·50				25795·4
3875·23	n			25797·2
3875·14				25797·8
3874·93				25799·2
3874·76				25800·3
3874·32	8			25803·3
3874·16				25804·3
3873·92				25805·9
3873·70				25807·4
3873·52				25808·6
3873·34				25809·8
3873·12	8			25811·3
3872·88	8			25812·9
3872·65	n			25814·4
3872·37	8			25816·3
3872·20				25817·4
3871·91				25819·3
3871·70				25820·8
3871·54	2nd edge			25821·8
	d g			
3871·17				25824·3
3871·02				25825·3
3870·83				25826·6
3870·68				25827·6
3870·50				25828·7
3870·27	8			25830·3
3870·07	8			25831·6
3869·78				25833·6
3869·53				25835·2
3869·31				25836·7
3869·20				25837·4
3868·94			7·8	25839·1
3868·73	d g			25840·5
3868·56				25841·6
3868·29				25843·4
3868·14	d g			25844·4
3867·94				25845·8
3867·77				25846·9
3867·54	d g			25848·4
3867·40				25849·4
3867·17	d g			25850·9
3866·95				25852·4
3866·68	d g			25854·2
3866·57				25854·9
3866·37				25856·3
3866·28	d g			25856·9
3866·13	8			25857·9
3865·78				25860·2
3865·67	d g			25860·9
3865·50				25862·1
3865·30	d g	1·16	7·8	25863·4
3865·17				25864·3

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3864·77	d g			25867·0
3864·66				25867·8
3864·44	8			25869·2
3864·24				25870·5
3864·16				25871·1
3863·80				25873·5
3863·70	d g			25874·1
3863 52	8			25875·3
3863·28				25876·9
3863·09				25878·2
3862·85				25879·8
3862·64	8 d g			25881·2
3862·48				25882·3
3862·12				25884·7
3861·98	8			25885·6
3861·86	3rd edge d g			25886·4
3861·70				25887·5
3861·45				25889·2
3861·30				25890·2
3861·15				25891·2
3860·99				25892·3
3860·78	8			25893·7
3860·59				25895·0
3860·37				25896·5
3860·11	d g			25898·2
3859·80	8			25900·3
3859·57				25901·8
3859·40	d g			25903·0
3859·30				25903·6
3859·09				25905·0
3858·96				25905·9
3858·81	8			25906·9
3858·62	d g			25908·2
3858·39				25909·8
3858·26	d g			25910·6
3858·03				25912·2
3857·82	8			25913·6
3857·63				25914·8
3857·49				25915·8
3857·29				25916·1
3857·07				25918·6
3856·82	8			25920·3
3856·58		1·16	7·8	25921·9
3856·39				25923·2
3856·17				25924·7
3856·03				25925·6
3855·76	8			25927·4
3855·56				25928·8
3855·45				25929·5
3855·26				25930·8

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3855·06	4th edge			25932·1
3854·99				25932·6
3854·82				25933·7
3854·70				25934·6
3854·48	d g			25936·0
3854·21				25937·9
3854·01				25939·2
3853·88				25940·1
3853·65				25941·6
3853·53				25942·4
3853·36				25943·6
3853·19				25944·7
3853·06				25945·6
3852·86				25946·9
3852·54	8			25949·1
3852·29				25950·8
3852·01				25952·7
3851·82				25953·9
3851·68				25954·9
3851·41	8			25956·7
3851·30				25957·5
3851·02				25959·3
3850·80				25960·8
3850·66	d g			25961·8
3850·44				25963·3
3850·30	8			25964·2
3850·07	d g			25965·8
3849·88				25967·0
3849·61				25968·9
3849·46	d g			25969·9
3849·14	8			25972·0
3848·98	n			25973·1
3848·76				25974·6
3848·45				25976·7
3848·35	d g			25977·4
3848·22				25978·2
3847·98	8			25979·9
3847·59				25982·5
3847·41				25983·7
3847·11	d g			25985·7
3846·95				25986·8
3846·79				25987·9
3846·65				25988·8
3846·44				25990·3
3846·13				25992·4
3845·93				25992·7
3845·58	8			25996·1
3845·46				25996·9
3845·37				25997·5
3845·15				25999·0
3845·01	8			25999·9
3844·80	d g			26001·3
3844·57				26001·9
3844·35	8			26004·4
3844·13				26004·9

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3843·94				26006·2
3843·81		1·15		26008·1
3843·59	d g			26009·5
3843·46				26010·4
3843·35				26011·2
3843·12	8			26012·7
3842·78				26015·0
3842·57				26016·5
3842·34				26018·0
3842·08				26019·8
3841·86	8			26021·2
3841·62				26022·9
3841·54				26023·4
3841·28				26025·2
3841·07				26026·6
3840·58	8			26029·9
3840·22				26032·4
3839·95	8			26034·2
3839·84				26034·0
3839·60				26036·6
3839·50		1·15	7·8	26037·3
3839·29	8			26038·7
3838·85				26041·7
3838·47				26044·3
3838·30				26045·4
3837·97	8			26047·6
3837·75				26049·1
3837·54				26050·6
3837·42				26051·4
3837·22				26052·7
3837·01				26054·2
3836·64	8			26056·7
3836·44				26058·0
3836·23				26059·5
3835·91				26061·6
3835·67				26063·3
3835·48				26064·6
3835·29	8			26065·9
3835·02				26067·7
3834·96				26068·1
3834·72	d g			26069·7
3834·58				26070·7
3834·34				26071·3
3834·14	d g			26073·7
3833·93	8			26075·1
3833·73				26076·5
3833·56				26077·6
3833·31				26079·3
3833·18				26080·2
3833·00				26081·4
3832·78				26082·9
3832·55	8			26084·5
3832·17				26086·1
3831·96	8			26088·5
3831·75				26089·9
3831·49				26091·7
3831·33				26092·8
3831·15	8			26094·0
3830·95				26095·4
3830·75	8			26096·7
3830·47				26098·7
3830·17				26100·7
3829·98				26102·0
3829·74	8			26103·6
3829·57				26104·8
3829·46				26105·5
3829·17				26107·5
3828·97				26108·9
3828·81				26110·0
3828·60				26111·4
3828·31	8			26113·4
3828·05	d g			26115·2
3827·74		1·15	7·9	26117·2
3827·49				26118·9
3827·04				26122·0
3826·84	8			26123·3
3826·61				26124·9
3826·44				26126·0
3826·30				26127·0
3826·17				26127·9
3826·03				26128·8
3825·77				26129·6
3825·40	8			26132·2
3825·27				26134·0
3825·09		1·15	7·9	26135·3
3824·89				26136·6
3824·65				26138·3
3824·47				26139·5
3824·16				26141·6
3823·90	8			26143·4
3823·64				26145·2
3823·40				26146·8
3823·18				26148·3
3822·95				26149·9
3822·74				26151·3
3822·43	8			26153·5
3822·17				26155·2
3821·88	8			26157·2
3821·53				26159·6
3821·30				26161·2
3820·89	8			26164·0
3820·69				26165·4
3820·50				26166·6
3820·24				26168·5
3820·03				26169·9
3819·84				26171·2
3819·52				26173·5
3819·36	8			26174·5
3819·15				26175·9
3818·79				26178·4

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3818·56				26180·0	3804·25		1·14		26278·5
3818·34				26181·5	3804·04				26279·9
3818·21				26182·4	3803·74				26282·0
3817·95				26184·2	3803·62				26282·8
3817·79	8			26185·3	3803·27				26285·3
3817·48				26187·4	3803·16	8			26286·0
3817·24				26189·0	3802·88				26288·0
3817·11				26189·9	3802·30				26292·0
3816·71				26192·5	3801·94				26294·5
3816·36				26195·1	3801·71				26296·1
3816·24	8			26195·9	3801·43	8			26298·0
3815·89				26198·3	3801·21				26299·5
3815·61				26200·2	3800·96				26301·3
3815·33				26202·2	3800·74				26302·8
3815·18				26203·2	3800·65				26303·4
3814·95				26204·8	3800·41				26305·1
3814·67	8			26206·7	3800·14	8			26306·9
3814·44		1·15	7·9	26208·3	3799·73	8			26309·8
3814·08				26210·7	3799·26				26313·0
3813·92				26211·8	3798·98				26315·0
3813·58				26214·2	3798·71				26316·8
3813·42				26215·3	3798·60				26317·6
3813·20				26216·8	3798·17				26320·6
3813·08				26217·6	3798·00	8			26321·8
3812·99				26218·2	3797·78				26323·3
3812·64				26220·6	3797·55				26324·9
3812·29				26223·1	3797·29				26326·7
3812·11				26224·3	3797·02	8			26328·6
3811·78				26226·6	3796·67				26331·0
3811·44	8			26228·9	3796·40				26332·8
3810·88				26232·8	3796·23	8			26334·0
3810·65				26234·3	3795·85				26336·7
3810·37				26236·3	3795·43				26339·6
3810·04				26238·5	3795·13				26341·7
3809·82	8			26240·1	3794·96				26342·8
3809·55				26241·9	3794·67				26344·9
3809·23				26244·1	3794·45				26346·4
3809·13				26244·8	3794·21				26348·1
3808·80				26247·1	3793·84	8			26350·6
3808·48	8			26249·3	3793·52				26352·8
3808·24		1·15	7·9	26250·6	3793·23				26354·9
3808·04				26251·9	3792·98				26356·6
3807·75				26254·0	3792·70	8			26358·5
3807·60				26255·1	3792·48				26360·1
3807·23				26257·8	3792·22	8			26361·9
3806·94				26259·9	3791·96				26363·7
3806 72				26261·5	3791·73				26365·3
3806·51	8			26263·0	3791·53				26366·7
3806·24				26264·9	3791·28				26368·4
3805·88				26267·2	3791·17				26369·2
3805·60				26269·2	3790·91				26371·0
3805·50				26269·8	3790·60				26373·1
3805·24				26271·7	3790·23				26375·7
3804·81	8			26274·6	3790·04				26377·0
3804·58				26276·2	3789·89				26378·1

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda +$	$\frac{1}{\lambda} -$				$\lambda +$	$\frac{1}{\lambda} -$	
3789·58				26380·2	3776·45				26471·9
3789·11				26383·5	3776·28				26473·1
3788·93				26384·8	3776·07	8			26474·6
3788·75				26386·0	3775·59		1·14	8·0	26477·9
3788·58				26387·2	3775·35	8			26479·6
3788·33				26389·0	3775·08				26481·5
3788·18				26390·0	3774·91				26482·7
3788·04				26391·0	3774·68	n			26484·3
3787·96				26391·5	3774·40				26486·3
3787·54				26394·5	3774·16	8			26488·0
3787·27	8			26396·3	3773·84				26490·2
3787·01				26398·2	3773·60	8			26491·9
3786·82				26399·5	3773·31				26494·0
3786·57				26401·2	3773·05				26495·8
3786·32				26403·0	3772·65				26498·6
3786·05			8·0	26404·7	3772·56				26499·2
3785·87				26406·0	3772·24	8			26501·4
3785·64				26407·6	3771·87	8			26504·0
3785·42				26409·1	3771·48				26506·8
3785·11				26411·3	3771·21				26508·7
3784·86				26413·1	3770·96				26510·4
3784·52	n			26415·4	3770·70				26512·1
3783·95				26419·4	3770·32				26514·9
3783·60	8			26421·8	3770·09				26516·6
3783·34				26423·7	3769·85				26518·3
3783·13				26425·1	3769·60				26520·0
3782·69				26428·2	3769·44				26521·1
3782·48				26429·7	3769·00				26524·2
3782·36				26430·5	3768·73		1·13		26526·1
3782·25				26431·3	3768·37	8			26528·7
3781·99				26433·1	3768·25				26529·5
3781·75	8			26434·8	3767·90				26532·0
3781·52				26436·4	3767·66				26533·7
3781·31				26437·9	3767·51				26534·7
3781·11				26439·3	3767·37				26535·7
3780·95				26440·4	3767·27				26536·4
3780·85				26441·1	3767·02				26538·2
3780·58				26443·0	3766·96				26538·6
3780·35				26444·6	3766·63				26540·9
3780·11				26446·3	3766·50				26541·8
3779·87	8			26447·9	3766·39				26542·6
3779·59				26449·9	3766·16				26544·2
3779·36				26451·5	3765·89				26546·1
3779·01				26454·0	3765·65				26547·8
3778·87				26454·9	3765·40				26549·6
3778·59				26456·9	3764·97		1·13	8·0	26552·6
3778·41				26458·2	3764·70				26554·5
3778·21				26459·6	3764·41	8			26556·6
3777·98	8			26461·2	3764·16				26558·3
3777·77				26462·6	3763·90				26560·2
3777·52				26464·4	*3763·65				26561·9
3777·37				26465·4	3763·35				26564·1
3777·18	8			26466·8	3763·05				26566·2
3776·92				26468·6	3762·91				26567·2
3776·79				26469·5	3762·41	8			26570·7

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3762·11				26572·8	3746·52				26683·4
3761·90				26574·1	3746·15	8			26686·1
3761·69				26575·6	3745·94			8·1	26687·5
3761·47				26577·2	3745·69				26689·0
3761·08	8			26580·1	3745·44				26691·1
3760·64				26583·2	3745·15				26693·1
3760·42	8			26584·3	3744·78				26695·7
3760·14				26586·7	3744·19				26699·9
3760·04				26587·5	3744·07	8			26700·8
3759·82				26589·0	3743·74				26703·0
3759·24				26593·1	3743·49				26704·9
3758·62				26595·5	3743·06				26708·0
3758·40	8			26597·1	3742·67				26710·8
3758·10				26599·2	3742·33				26713·2
3757·90				26602·6	3741·96	8			26716·0
3757·60				26604·7	3741·80				26717·0
3757·40				26606·1	3741·37				26720·1
3757·14				26608·0	3741·20				26721·3
3757·02				26608·8	3740·96				26723·0
3756·72				26611·0	3740·60				26725·6
3756·40	8			26613·1	3740·42				26726·9
3756·11				26615·3	3740·14				26728·9
3755·90				26616·8	3739·86	8			26730·9
3755·58				26619·0	3739·63				26731·5
3755·39				26620·4	3739·24				26735·3
3755·25				26621·4	3739·07				26736·5
3754·91				26623·8	3738·51	8			26740·5
3754·63				26625·8	3737·93				26744·7
3754·37				26627·6	3737·74				26746·0
3754·13				26629·3	3737·53				26747·5
3753·69				26632·4	3737·23				26749·7
3753·49				26633·9	3736·58	8	1·13	8·1	26754·3
3753·27				26635·4	3736·17	n			26757·3
3752·95				26637·7	3735·73				26760·4
3752·66				26639·8	3735·57				26761·6
3752·33	8			26642·1	*3735·29				26763·6
3752·07				26644·0	3735·00				26765·7
3751·82				26645·7	3734·64				26768·2
3751·58				26647·4	3734·41				26769·9
3751·15				26650·5	3734·06	n			26772·4
3750·87				26652·5	3733·50	8			26776·4
3750·64				26654·1	3733·13				26779·1
3750·27				26656·8	3732·98				26780·2
3749·94				26659·1	3732·70				26782·2
3749·61				26661·4	3731·89		1·13		26788·0
3749·25				26664·0	3731·65		1·12		26789·7
3748·95				26666·1	3731·37	8			26791·7
3748·73				26667·7	3731·01				26794·1
3748·43				26669·8	3730·74				26796·2
3748·21				26671·4	3730·44				26798·4
3748·06				26672·5	3730·16				26790·4
3747·76				26674·6	3729·73	n			26803·5
3747·52				26676·3	3729·21	8			26807·2
3747·14				26679·0	3728·82	8			26810·0
3746·67				26682·4	3727·74				26817·8

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
3727·48				26819·7	3705·47				26978·9
3727·27				26821·2	3705·11	8, n			26981·5
3727·07	8			26822·6	3704·20				26988·2
3726·86				26824·1	3703·86	n			26990·7
3726·62				26825 9	3703·53				26993·1
3726·23				26828·7	3703·32				26994·6
3725·75				26832·1	3703·10				26996·2
3725·33				26835·2	3702·92	8			26997·5
3724·91	8			26838·2	3702·62				26999·7
3724·47				26841·4	3701·98				27004·4
3723·98				26844·9	3701·65				27006·8
3723·60				26847·6	3701·54				27007·6
3723·19				26850·6	3701·10				27010·8
3722·94				26852·4	3700·71	8			27013 6
3722·74	8			26853·8	3699·94				27019·3
3722·27				26857·2	3699·43				27023·0
3721·41				26863·4	3699·11				27025·3
3720·94				26866·8	3698·90				27026·9
3720·56	8			26869·6	3698·70				27028·3
3720·08	8			26873·0	3698·48	8			27029·9
3719·57				26876·7	3698·26				27031·5
3719·03				26880 6	3697·94		1·12	8·2	27033·9
3718·80				26882·3	3697·47				27037·3
3718·56				26884·0	3697·12	8			27039·9
3718·38	8			26885·3	3696·85				27041·9
3717·53	n			26891·5	3696·58				27043·8
3717·11				26894·5	3696·24	8			27046·3
3717·01				26895·2	3695·81	n			27049·5
3716·50				26898·9	3695·13				27054·4
3716·19	8			26901·2	3694·95				27055·8
3715·74				26904·4	3694·76				27057·2
3715·32				26907·5	3694·27				27060·8
3715·00				26909·8	3694·01	8			27062·7
3714·68				26912·1	3693·74				27064·6
3714·40				26914·2	3693·17	n			27068·8
3713 99	8			26917·1	3691·75	8			27079·2
3713·61				26919·9	3691·17				27083·5
3713·02	8			26924·2	3690·05				27091·7
3712·29	n			26929·5	3689·76				27093·8
3711·81	8			26932·9	3689·51	8			27095·7
3711·39				26936·0	3689·21				27097·9
3711·04				26938·5	3688·47				27103·3
3710·71				26940·9	3687·65				37109·3
3710·41				26943·1	3687·26				37112·2
3709·61	8			26948·9	3686·86				27115·2
3709·40				26950·4	3686·58				27117·2
3709·05				26953·0	3685·97				27121·7
3708·41				26957·4	3685·25				27127·0
3708·02			8.1	26960·5	3685·01	8			27128·8
3707·66			8·2	26963·0	3683·98				27136·4
3707·38				26965·0	3683·69				27138·5
3707·07				26967·3	3683·29				27141·4
3706·72				26969·8	3682·78	8			27145·2
3706·40				26972·2	3682·45				27147·6
3705·71				26977·2	3681·93				27151·5

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3681·33	8			27155·9	3657·36				27333·8
3680·51	8			27161·9	3657·03				27336·3
3679·75				27167·6	3656·76				27338·3
3679·36	8			27170·1	3656·50				27340·3
3679·11				27172·3	3656·26				27342·1
3678·77				27174·8	3656·08				27343·4
3678·52				27176·7	3655·82	8			27345·3
3678·26	8	1·11	8·2	27178·6	3655·44	n			27348·2
3677·98				27180·6	3655·00				27351·5
3677·66				27183·0	3654·36	n			27356·2
3677·40				27184·9	3653·62	8			27361·8
3677·20				27186·4	3653·23				27364·7
3676·54				27191·3	3652·86				27366·5
3676·27				27193·3	3652·55				27369·8
3676·01	8			27195·2	3652·23				27372·2
3675·51				27198·9	3651·41	8			27378·4
3675·14				27201·6	3650·79	n			27383·0
3674·77				27204·4	3649·74				27390·9
3673·75	8			27211·9	3649·44				27392·2
3673·58				27213·2	3649·18				27395·1
3673·04				27217·2	3648·81			8·3	27397·9
3672·47				27221·4	3648·51				27400·1
3671·98				27225·1	3648·29				27402·8
3671·64				27227·6	3647·99	8			27404·1
3671·50	8			27228·6	3647·67				27406·5
3670·65				27234·9	3647·36				27408·8
3669·74	8			27241·7	3647·00				27411·5
3669·26	8			27245·3	3646·79				27413·1
3668·08				27254·0	3646·34				27416·5
3667·86				27255·7	3645·92				27419·8
3667·68				27257·0	3645·40				27423·6
3667·19				27260·5	3645·14				27425·5
3667·00	8			27262·0	3644·80				27428·0
3666·69				27264·3	3644·67				27429·0
3665·95				27269·8	*3644·26	8			27432·1
3665·61				27272·3	3643·56				27437·4
3664·77	8			27278·5	3643·35				27439·0
3664·44				27281·0	3643·10				27440·8
3664·11				27283·5	3642·81				27443·0
3663·95				27284·6	3642·63	8			27444 4
3663·21				27290·2	3642·27	n			27447·1
3662·97				27292·0	3641·91				27449·8
3662·53	8			27295·2	3641·47				27453·1
3662·22	8, n			27297·5	3641·11	8			27455·8
3661·86				27300·2	3640·70				27458·9
3661·23	n			27304·9	3640·46	8			27460·8
3660·39				27311·2	3640·29				27462·0
3660·29				27311·9	3638·29	8			27477·1
3659·67		1·10		27316 6	3637·27	8			27484·8
3659·32				27319·2	3636·35	8			27491·8
3659·08				27321·0	3636·06				27494·0
3658·83				27322·8	3635·64				27497·2
3658·60				27324·6	3635·48				27498·4
3658·31				27326·7	3635·20	8			27500 5
3658·05	8			27328·7	3634·67	n			27504·5

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3634·10				27508·8	3617·30				27636·5
3633·85				27510·7	3617·19				27637·4
3633·44				27513·8	3617·03				27638·6
*3633·05	8			27516·8	3616·48				27642·8
3632·66				27519·7	3616·23	n			27644·7
3632·22	n			27523·1	3615·91	n			27647·2
3631·91				27525·4	3615·38				27651·2
3631·61	8			27527·7	3615·18				27652·7
3631·21	n			27530·7	3614·81				27655·6
3630·80				27533·8	3614·46				27658·3
3630·62				27535·2	3614·30	n			27659·5
3630·03				27539·7	3614·09	n			27661·1
3629·89				27540·7	3613·78				27663·5
3629·64				27542·6	3613·41				27666·3
3629·31	8			27545·2	3613·26				27667·4
3629·18				27546·1	3612·74	n			27671·4
3628·86	n		8·4	27548·5	3612·56				27672·8
3628·47				27551·4	3612·22				27675·4
3628·15				27553·9	3612·05				27676·7
3627·87				27556·0	3611·84				27678·3
3627·71				27557·2	3611·70				27679·4
3627·57				27558·3	3611·42				27681·5
3627·18				27561·2	3611·20				27683·2
3626·99				27562·7	3610·90				27685·5
3626·46				27566·7	3610·69				27687·1
3626·25				27568·3	3610·53				27688·4
3625·80				27571·7	3610·35				27689·7
3625·68				27572·6	3610·16				27691·2
3625·33	n			27575·3	3609·84				27693·7
3625·00				27577·8	3609·69				27694·8
3624·72				27579·9	3609·48				27695·4
3624·18	8			27583·1	3609·33				27697·6
3624·01				27585·3	3609·17				27698·8
3623·66	n	1·10	8·4	27587·7	3608·98				27700·3
3623·41				27589·3	3608·84				27701·3
3623·14	n			27591·1	3608·70				27702·4
3622·73				27595·1	3608·46				27704·3
3622·58	n			27596·2	3608·33				27705·3
3622·14	n	1·09		27599·6	3608·17				27706·5
3621·84				27601·9	3607·88	8			27708·7
3621·60				27603·7	3607·69				27710·2
3621·17				27607·0	3607·40	8			27712·4
3621·02				27608·1	3607·27				27713·4
3620·55				27611·7	3606·94	8			27715·9
3620·34				27613·3	3606·79				27717·1
3619·90				27616·7	3606·47	8			27719·6
3619·62				27618·8	3606·28				27721·0
3619·32				27621·1	3606·01	8			27723·1
3619·13	8			27622·5	3605·78		1·09	8·4	27724·9
3618·91		1·09	8·4	27624·2	3605·56	8			27726·5
3618·73				27625·6	3605·31				27728·5
3618·43				27627·9	3605·09	8			27730·2
3618·16				27630·0	3604·82				27732·2
3617·76				27633·0	3604·69	8			27733·2
3617·61				27634·2	3604·57				27734·2

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3604·23	8			27736·8
3603·76	n			27740·4
3603·36				27743·5
3603·21				27744·7
3602·92	8, n			27746·9
3602·61				27749·3
3602·49				27750·2
3602·35				27751·3
3602·18				27752·6
3602·04				27753·6
3601·89				27754·8
3601·67				27756·5
3601·58				27757·2
3601·44				27758·3
3601·27				27759·6
3601·12				27760·7
3601·01				27761·6
3600·68				27764·1
3600·60				27764·7
3600·25				27767·5
3599·89	n			27770·2
3599·60	n			27772·5
3599·37				27774·2
3599·19				27775·6
3598·99				27777·2
3598·85				27778·3
3598·60				27780·2
3598·46				27781·3
3598·26				27782·8
3598·12				27783·9
3597·85	8			27786·0
3597·57				27788·2
3597·45				27789·1
3597·25				27790·6
3597·09				27791·9
3596·89				27793·4
3596·73				27794·6
3596·55				27796·0
3596·38				27797·3
3596·19				27798·8
3596·04				27800·0
3595·82				27801·7
3595·63				27803·1
3595·45				27804·5
* 3595·23				27806·2
* 3595·01				27807·9
3594·75				27809·9
3594·55				27811·5
3594·26	8, n			27813·7
3594·07				27815·2
3593·82	8			27817·1
3593·61				27818·8
3593·40	8			27820·4
3593·05				27823·1
3592·92				27824·1

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3592·69				27825·9
3592·34				27828·6
3592·00				27831·2
3591·62				27834·2
3591·28			8·5	27836·8
3591·12				27838·1
3591·03				27838·8
3590·82				27840·4

Fourth Band of the Cyanogen Spectrum

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3590·48	1st edge	1·09	8·5	27842·9
3590·13				27845·6
3590·01				27846·6
3589·87				27847·7
3589·71				27848·9
3589·58				27849·9
3589·43				27851·1
3589·24				27852·6
3589·06				27854·0
3588·87				27855·4
3588·67				27857·0
3588·44				27858·8
3588·22				27860·5
3587·98				27861·3
3587·71				27864·4
3587·46				27866·4
3587·21				27868·3
3586·91				27870·6
3586·64	n			27872·4
3586·28	n	1·08		27875·5
3585·95	2nd edge			27880·2
3585·63				27880·6
3585·35				27882·8
3585·20				27883·9
3585·04				27885·2
3584·88				27886·4
3584·73				27887·6
3584·62				27888·5
3584·44				27889·9
3584·21				27891·7
3584·06	3rd edge			27892·8
3583·83				27894·6
3583·58	8			27896·6
3583·44				27898·4
3583·09				27900·4
3582·84				27902·3
3582·69				27903·5
3582·53				27904·7
3582·44				27905·4
3582·31				27906·4
3582·15				27907·7
3581·97	8			27909·1

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda +$	Reduction to Vacuum $\frac{1}{\lambda} -$	Oscillation Frequency in Vacuo
3581·72	8			27911·0	3571·10				27994·1
3581·53				27912·5	3570·91				27995·6
3581·35				27913·9	3570·55	8			27998·4
3581·08	n			27916·0	*3570·40				27999·6
3580·88	n			27917·6	3570·20				28001·1
3580·69				27919·1	3569·92	8			28002·3
3580·59				27919·9	3569·85	8			28003·9
3580·35	8			27921·7	3569·64				28005·5
3580·10				27923·7	3569·38				28007·6
3580·03	8, n			27924·2	3569·13	8			28009·5
3579·81				27925·9	3568·90				28010·3
3579·63				27927·4	3568·75				28012·5
3579·48				27928·5	3568·58				28013·9
3579·22	8, n			27930·6	3568·40	8			28015·3
3578·89	8			27933·1	3568·15				28017·2
3578·58	8	1·08	8·5	27935·5	3568·02				28018·3
3578·46				27936·5	3567·86				28019·5
3578·24	8			27938·2	3567·70				28020·8
3578·03				27939·8	3567·49	8			28022·4
3577·89				27940·9	3567·30				28023·9
3577·67				27942·7	3566·98	8			28026·4
3577·56				27943·5	3566·89	8			28027·1
3577·43				27944·5	3566·63				28029·2
3577·19	8			27946·4	3566·48				28030·4
3576·84	8			27949·1	3566·23	8			28032·3
3576·72				27950·1	3566·01				28034·0
3576·44	8			27952·3	3565·72				28036·3
3576·26				27953·7	3565·55				28037·4
3576·07				27955·2	3565·45				28038·4
3575·69	8			27958·1	3565·14		1·08	8·5	28040·9
3575·56				27959·2	3564·91	8			28042·7
3575·43				27960·2	3564·70				28044·4
3575·27				27961·4	3564·53				28045·7
3575·09	8			27962·8	3564·22				28048·1
3574·86				27964·6	3564·06				28049·4
3574·67				27966·1	3563·92	8			28050·4
3574·46	8			27967·8	3563·54				28054·1
3574·24				27969·5	*3563·32				28055·2
3574·03				27971·1	3563·12				28056·8
3573·83	8			27972·7	3562·97				28058·0
3573·57				27974·7	3562·82				28059·2
3573·32				27976·7	3562·66				28060·4
3573·19				27977·7	3562·39				28062·6
3573·05				27978·8	3562·31				28063·2
3572·88				27980·2	3562·15				28064·4
3572·74				27981·3	3562·02				28065·5
3572·56	8			27982·7	3561·86				28066·7
3572·35				27984·3	3561·56	8 } dg			28069·1
3572·24				27985·2	3561·38	8 }			28070·5
3572·05				27986·6	3560·97				28073·7
3571·89	8			27987·9	3560·71	8			28075·8
3571·67				27989·6	3560·38				28078·4
3571·51				27990·9	3560·24				28079·5
3571·37				27992·0	3560·07				28080·8
3571·23	8			27992·1	3559·95				28081·8

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3559·83				28082·7	3548·63	8			28171·3
3559·71				28083·7	3548·32	8			28173·8
3559·39				28086·2	3548·09				28175·6
3559·25				28087·3	3547·95				28176·7
3559·11				28088·4	3547·75				28178·3
3558·99				28089·4	3547·52				28180·1
3558·70				28091·7	3547·31				28181·8
3558·59				28092·5	3547·14				28183·1
3558·47				28093·5	3546·90	8			28185·0
3558·16				28095·5	3546·71				28186·5
3558·00				28097·1	3546·58				28187·6
*3557·84				28098·4	3546·40				28189·0
3557·64				28100·0	3546·27				28190·0
3557·51				28101·1	3545·99				28192·3
3557·30	8			28102·7	3545·88	8			28193·1
3557·15				28103·9	3545·69				28194·7
3556·85				28106·3	3545·41	n			28196·9
3556·63				28108·0	3545·07	8			28199·6
*3556·41				28109·7	3544·70				28202·5
3556·09	8			28112·3	3544·36				28205·3
3555·86				28114·1	3544·23				28206·3
3555·51				28116·9	3544·11				28207·2
3555·32				28118·4	3543·74				28210·2
3555·16				28119·6	3543·61				28211·2
3555·00				28120·9	3543·46				28212·4
3554·81				28122·4	3543·26				28214·0
3554·63				28123·8	3543·08				28215·4
*3554·44	8			28125·3	3542·85				28217·3
3554·20				28127·2	3542·77				28217·9
3554·00				28129·0	3542·60				28219·3
3553·81			8·6	28130·2	3542·36				28221·2
3553·68	8			28131·2	3542·07				28223·5
3553·49				28132·8	3541·77				28225·9
3553·32				28134·4	3541·43				28228·6
3553·13				28135·6	3541·25				28230·0
3552·94				28137·1	3541·06				28231·5
3552·82	8			28138·1	3540·88				28233·0
3552·45				28141·0	3540·49	8			28236·1
3552·23				28142·7	3540·06	8			28239·5
3552·04				28144·2	3539·76				28241·9
3551·88				28145·5	3539·52				28243·8
3551·77				28146·2	3539·35				28244·2
3551·61				28147·6	3539·19				28246·5
3551·42				28149·2	3538·99				28248·0
3551·18				28151·1	3538·87				28249·0
3550·94				28153·0	3538·58	n			28251·3
3550·66		1·07	8·6	28155·2	3538·37				28253·0
3550·35				28157·6	3538·21				28254·3
3550·00				28160·4	3538·11				28255·1
3549·89				28161·3	3537·91				28256·7
3549·64				28163·3	3537·62	8			28259·0
3549·48				28164·5	3537·39	n			28260·8
3549·20				28166·8	3536·87				28265·0
3549·07	8			28167·8	3536·64	n			28266·8
3548·78				28170·1	3536·27				28269·8

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum		Oscillation Frequency in Vacuo
		$\lambda+$	$\frac{1}{\lambda}-$				$\lambda+$	$\frac{1}{\lambda}-$	
3536·14				28270·8	3522·36	n			28381·5
3535·99				28272·0	3522·07				28383·8
3535·79	n			28273·6	3521·85				28385·6
3535·66				28274·7	3521·65				28387·2
3535·51	n			28275·9	3521·36				28389·5
3535·28		1·07	8·6	28277·7	3521·15				28391·2
3535·01				28279·9	3520·94				28392·9
3534·71	8			28282·3	3520·78				28393·2
3534·22	n			28286·2	3520·53				28395·2
3533·86				28289·1	3520·28				28397·2
3533·64	n			28290·8	3519·97	8			28400·7
3533·40				28292·8	3519·73				28402·7
3532·99				28296·0	3519·23				28406·7
3532·88				28296·9	3519·00				28408·6
3532·70				28298·4	3518·80				28410·2
3532·53				28299·7	3518·57				28412·0
3532·36				28301·1	3518·14	n			28415·5
3532·02				28303·8	3517·91				28417·4
3531·73	n			28306·1	3517·68				28419·2
3531·43				28308·5	3517·40				28421·5
3531·13				28310·5	3517·12	8			28423·8
3531·08	n			28311·3	3516·64				28427·7
3530·72				28314·2	3516·42			8·7	28429·3
3530·52				28315·8	*3516·31				28430·2
3530·31	8			28317·5	3515·98	n			28432·9
3530·23				28318·2	3515·87				28433·8
3529·94				28320·5	3515·18				28439·3
3529·72				28322·3	3514·90				28441·6
3529·46				28324·5	3514·65				28443·6
*3529·23	n			28326·2	3514·40				28445·7
3528·71	8			28330·4	3514·15				28447·7
3528·40				28332·9	3514·02				28448·7
3528·10	n			28335·3	3513·83		1·06		28450·3
3527·70	8			28338·5	3513·22				28454·2
3527·46				28340·4	3512·75	8			28459·0
3526·95				28344·5	3512·49				28461·1
3526·78				28345·9	3512·32				28462·5
3526·56				28347·6	3512·20				28463·5
3526·40				28348·9	3511·92				28465·7
3526·20				28351·5	3511·61	8			28468·3
3526·04				28351·8	3511·29	n			28470·9
3525·80				28353·8	3510·53				28477·0
3525·60				28355·4	3510·34	8			28479·6
3525·47				28356·4	3509·81	n			28482·9
3525·28				28357·9	3509·44	8			28485·9
3525·13				28359·1	3509·10				28488·6
3524·66	8			28362·9	3508·45				28493·9
3524·47	8			28364·5	3508·33				28494·9
3523·99				28368·3	3507·87				28498·6
3523·73				28370·4	3507·72				28499·8
3523·47	8			28372·5	3507·52				28501·5
3523·23				28374·4	3507·23				28503·8
3523·00				28375·3	3507·03				28505·5
3522·82				28377·8	3506·61	8			28508·9
3522·49				28380·4	3506·38				28510·7

CYANOGEN (ARC SPECTRUM)—*continued.*

Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo	Wave-length (Rowland)	Intensity and Character	Reduction to Vacuum $\lambda+$	Reduction to Vacuum $\frac{1}{\lambda}-$	Oscillation Frequency in Vacuo
3506·12				28512·9	3494·91				28604·3
3505·64				28516·8	3494·52				28607·5
3505·38				28518·9	3494·00				28611·8
3505·18				28520·5	3493·80				28613·4
3504·69				28524·5	3493·67				28614·5
3504·52				28525·9	3492·73				28621·2
3504·14				28529·0	3492·29				28625·8
3503·79	8			28531·8	3491·93		1·06	8·7	28628·8
3503·24				28536·3	3491·50				28632·3
3502·88				28539·2	3491·07				28635·9
3502·73				28540·5	3490·72				28638·7
3501·90				28547·2	3490·48				28640·7
3501·63	8			28549·4	3490·19				28643·0
3501·33				28551·9	3489·39				28649·6
3501·02				28554·4	3488·87				28653·9
3500·50				28558·7	3488·49				28657·0
3500·36				28559·8	3488·19				28659·5
3499·72				28565·0	3487·61				28664·2
3499·39				28567·7	3487·09				28668·5
3499·09				28570·2	3486·33				28674·8
3498·64				28573·8	3486 06				28677·0
3498·25				28577·0	3485·37				28682·7
3497·85				28580·3	3484·99				28685·8
3497·17	8, n			28585·8	3484·59				28689·1
3496·57				28590·8	3483·81				28695·5
3496·33				28592·7	3483·05				28701·8
3496·03				28595·2	3482·74				28704·3
3495·42				28600·2	3482·41				28707·1
3495·22				28601·8					

An International Standard for the Analysis of Iron and Steel.—Fifth Report of the Committee, consisting of Professor W. C. ROBERTS-AUSTEN (*Chairman*), Sir F. ABEL, Mr. E. RILEY, Mr. J. SPILLER, Professor J. W. LANGLEY, Mr. G. J. SNELUS, Professor TILDEN, *and* Mr. THOMAS TURNER (*Secretary*). (*Drawn up by the Secretary.*)

IN the previous report of this Committee it was mentioned that, so far as the original four steel standards were concerned, the work of the British analysts was completed. It was also stated that the American Committee had nearly finished its labours on these standards, and hoped to publish the results in a few months. Owing to the long distances over which the members of the American Committee are scattered, and the fact that some of the members of the Committee have still been labouring at the question of methods of carbon determination, it was not found possible to hold a meeting as originally intended, but the results of the analyses were to be communicated to, and the questions raised discussed at, the World's Congress of Chemists at Chicago. Professor Langley has, however, forwarded an advance report of the analyses, which is appended, together with the

values obtained by the British analysts, which are added for comparison; the American results are subject to slight revision at Chicago, and should any alterations be made these will be inserted before this report is finally published.

I.—*Mean Results of the Analyses by the American Committee.*

Standard	No. 1	No. 2	No. 3	No. 4
Carbon	1·44	·80	·454	·18
Silicon	·270	·202	·152	·015
Sulphur	·004	·004	·004	·038
Phosphorus . . .	·016	·010	·015	·088
Manganese . . .	·254	·124	·140	·098

II.—*Mean Results of the Analyses by the British Committee.*

Standard	No. 1	No. 2	No. 3	No. 4
Carbon	1·414	·816	·476	·151
Silicon	·263	·191	·141	·008
Sulphur, not more than .	·006	·007	·008	·039
Phosphorus . . .	·018	·014	·021	·078
Manganese . . .	·259	·141	·145	·130

A report has also been forwarded by Professor Akerman on behalf of the Swedish Committee, but as the results included in this report have not yet been revised, they are intended for the guidance of the other committees, and not for publication. It may, however, be stated that the agreement between the Swedish and British reports is quite as good as that between the two above given.

Standard 5, the preparation of which was mentioned in the previous report of this Committee, has been hermetically sealed in glass tubes, like Standards 1, 2, 3, and 4. It was thought well not to proceed with the analysis of this standard until an opportunity had been afforded of comparing the results obtained by the various committees on the analyses of the standards already under examination. Otherwise, after the work of the British analysts was completed, questions as to methods of analysis or other points of detail might have arisen, without a convenient opportunity being afforded for their investigation.

Now that reports from three out of the five International Committees are at hand for comparison, they will be considered by this Committee, and the analysis of the remaining standard completed.

On Solution.—Report of the Committee, consisting of Professor W. A. Tilden *(Chairman)*, Dr. W. W. J. Nicol *(Secretary)*, *and* Professor W. Ramsay.

The Committee have continued their work on the lines laid down in the report of last year, but the progress made and the results obtained are not such as to warrant the publication of any general conclusions at present. The Committee intend to continue their investigations, and therefore desire reappointment without a grant.

The Influence of the Silent Discharge of Electricity on Oxygen and other Gases.—Report of a Committee, consisting of Professor H. McLeod (*Chairman*), Mr. W. A. Shenstone (*Secretary*), Professor W. Ramsay, *and* Mr. J. Tudor Cundall. (*Drawn up by the Secretary.*)

This Committee was first appointed in 1885; grants of money were made in that and in the succeeding year. The expenditure of these grants has already been duly reported. It therefore only remains to give an account of the work that has been done. This has already been fully described in the 'Journal of the Chemical Society' and elsewhere, and consequently it will be sufficient now to give an outline of the results obtained, with references to the fuller descriptions.

I. *The Preparation and Storage of Oxygen.*[1]

In this note a method of preparing oxygen from a mixture of the chlorates of sodium and potassium was described. The process recommended has been found to be very convenient, and has since been adopted by other investigators. Its advantage lies in the ready fusibility of the mixture, and the consequent reduced risk of breaking glass apparatus in which the chlorate must be submitted to repeated fusion and solidification in the course of generating oxygen from it.

II. *Ozone from Pure Oxygen. Its Action on Mercury, with a Note on the Silent Discharge of Electricity.*[2] *By* W. A. Shenstone *and* J. Tudor Cundall.

The experiments described in this paper showed that a good yield of ozone (7·5 per cent.) is readily obtained from carefully dried oxygen.

It has lately been suggested by Professor Armstrong that, in spite of the care taken, it is possible impurity may have been introduced into the gas by the action of the discharge, which might conceivably detach adherent moisture from the glass surfaces of the apparatus. Moreover, when these experiments were made the only liquid that was available for use in the manometers was oil of vitriol, and though this was screened from the dried oxygen by phosphoric anhydride, its use introduced a fresh element of uncertainty.

On the other hand, the proportion of ozone obtained was, considering the form of apparatus employed, sufficiently high to suggest that the conditions of the experiment were very favourable to the production of a high yield of ozone, and the mixture of ozone and oxygen obtained by the discharge was apparently without *chemical* action on mercury, which is inconsistent with the idea that moisture was present in it, whilst it is stated by Brodie in his 'Classical Research' that in order to obtain a high yield of ozone *dry* oxygen must be employed.

The later experiments described in section III. will make it possible to investigate this point more severely than in 1885, and therefore this important question will very shortly be re-examined.

[1] *British Assoc. Rep.*, 1886. [2] *Journ. Che*

III. *Studies on the Formation of Ozone from Oxygen.*[1] *By* W. A. Shenstone *and* Martin Priest.

The introduction of improved methods of working with ozone have enabled the authors of this paper to study the influence of various conditions on the converting of oxygen into ozone with increased exactness and facility.

The results obtained show that—

1. Under constant conditions it is possible to obtain concordant results in converting oxygen into ozone by the silent discharge.

2. That the maximum yield of ozone is nearly independent of the difference of potential employed to produce the discharge (the range of potential difference employed was from 33 to 69 C.G.S. units), provided that the path of the discharge be not too short.

3. That if the path of the discharge be very short, then the maximum yield of ozone has an inverse relation to the difference of potential employed.[2]

4. The rapidity with which the discharge converts oxygen into ozone is greater when great potential differences are employed than for smaller differences.

5. That the maximum yield of ozone is less when the number of discharges is *very* great in unit time than when it is smaller.[3] But the yield is not affected by moderate variations of rapidity of the discharge.

6. The greatest yield of ozone was obtained by using an ozone generator made of the thinnest possible glass, and with closely fitting tubes. In one case 17·15 per cent. of ozone was obtained at 0°.

7. Under equal conditions less ozone was produced by the discharge obtained by means of a Wimshurst's machine than when a large induction coil was employed.

It has been suggested that this last phenomenon may be due to a difference in the quantity of electricity acting in the two cases, but the authors point out that under the conditions of their experiments[4] the 'quantity' of the discharge inside the ozone generator depends on the difference of potential of the inducing charge, and that as the ozonising effect of the discharge is, under suitable conditions (see 2 and 3 above), independent of the potential difference of the inducing charge, it would seem that this suggestion does not afford a clue to the cause of the phenomenon. Moreover, it was found in the experiments made with the plate machine that when the quantity of the inducing charge was raised or reduced, by means of condensers, the yield of ozone remained unaffected.

Although a good deal of progress has now been made, much of the work undertaken remains to be done. As, however, no further grants are likely to be asked for, and as it is probable that in the future the work will be mainly in the hands of one member of the Committee, the Committee now recommend that they be not reappointed.

[1] *Journ. Chem. Soc.*, 1893.

[2] This is attributed to the difficulty of maintaining a sufficiently regular temperature of the gas under these circumstances.

[3] This is also probably due to imperfect refrigerating.

[4] Ozonisers of Brodie's type were employed.

Bacteriology in its Relations to Chemical Science.—By PERCY FRANKLAND, *Ph.D., B.Sc. (Lond.), F.R.S., Professor of Chemistry in University College, Dundee, St. Andrews University.*

[Ordered by the General Committee to be printed *in extenso.*]

IN science as in politics there are certain territories which. whilst unable to fully assert their own independence, are yet so jealously watched by their powerful neighbours that deliberate annexation by any one of these is impossible. Such semi-independent states usually become successively subject to the influence of their more powerful neighbours, each of which is anxious to acquire an ascendency in their councils.

In science such a semi-independent state is bacteriology, of hardly sufficient importance to stand by itself, but surrounded as it is by its great neighbours Botany, Medicine, and Chemistry, to each of which in part it owes its present prominent position, both in the scientific and unscientific worlds.

Originally an offshoot of Botany, from which also in its early infancy it received such powerful support through the memorable ministrations of Cohn, of Naegeli, and of Brefeld, but although thus under obligation to the parent science, the greatest impulse given to the study of bacteria will always be associated with Chemistry in the person of M. Pasteur, whilst there can be no doubt that by far the greater part of our more recent knowledge concerning these micro-organisms has been acquired through the indefatigable labours of medical men, so many of whom have been fired by the brilliant discoveries of Koch, Metchnikoff, and Behring.

In these bacteriological investigations, however, the medical man has been constantly brought more and more into the domain of Chemistry, so that, starting with phenomena which he at first regarded from a purely biological, *i.e.*, a more or less superficial and empirical, point of view, he has by more profound study in many cases reached the chemical, physical, and mechanical foundations on which all biological phenomena must of necessity rest.

As, therefore, the history and development of bacteriology are so intimately connected with Chemistry, and as it is to chemical science that we must ultimately look for the elucidation of innumerable bacteriological phenomena, it is only natural that our President should have desired to see this subject brought before this Section. It is, however, with extreme diffidence and hesitation that I have undertaken at his request to introduce this discussion to-day, as from the great breadth of the subject, with its numerous ramifications into other sciences, the task is in many respects peculiarly arduous and beset with extraordinary peril. I will, however, at once state that I have no intention of burdening you with a detailed survey of the present position of bacteriology, but that it is only my purpose to refer to some matters which have recently been attracting the attention of investigators, and which may possibly interest the members of the Chemical Section.

Methods.—What may be called modern bacteriology commences with the introduction, now some twelve years ago, of the systematic methods of obtaining pure cultivations of micro-organisms; for although a number

of bacteriological problems can be, and have been, solved by experimenting with casual mixtures of microbes, progress in many directions was necessarily barred until particular organisms could be obtained and maintained in a state of purity for investigation.

That these methods have now reached a high state of perfection is attested by the fact that, in spite of the great number of persons who are constantly using them in all parts of the world, no changes of any great importance have been made during the past few years. A general understanding of these methods of bacteriology may now be said to constitute almost an integral part of a liberal education, although, judging from the flagrant inaccuracies which are to be found in the numerous references to matters bacteriological in the daily press, it is evident that the newspaper correspondents who undertake to inform the public on these topics have not, as a rule, had the benefit of the liberal education in question.

Perhaps the circumstance most calculated to impress the British public with the present importance of bacteriology is that pure cultivations of micro-organisms have now for some years past become actually articles of commerce. Not only are pure yeasts, prepared according to Hansen's methods, in circulation all over the world, but pure cultivations of pathogenic and other bacteria can now be purchased at catalogue prices, to the great convenience of the investigator, in much the same way as we have been in the habit of procuring pure and inaccessible chemicals from Kahlbaum's. Again, bacterial poisons have been employed in various parts of the world for combating animal plagues, whilst domesticated bacteria have been used for the preventive inoculation of cattle and other animals.

If, however, the general methods of bacteriological study have undergone but little change recently, the greatly increased attention which has been given to the study of particular forms isolated by these methods has led to some important developments in our views concerning bacteria in general.

Although the discovery of the existence of micro-organisms was necessarily made with the microscope, and the earlier information concerning them obtained almost exclusively by means of this instrument, the introduction of the modern bacteriological methods soon relegated the microscope to a secondary position for the purpose of their differentiation and diagnosis. It was early found that bacteria which were perfectly undistinguishable when viewed through the microscope might exhibit the most marked differences in their macroscopic appearances and in their functions. Using the modern methods of bacteriological study, indeed, the investigator generally becomes acquainted with such macroscopic differences amongst micro-organisms before the microscope is brought into requisition at all. It results from this that in examining any given material the number of different bacteria discovered by cultivation methods will generally greatly exceed that revealed by microscopic examination alone. Upon the introduction of these cultivation methods there rapidly followed, then, the discovery of a large number of different kinds of bacteria obtained from the most varied sources, tissues healthy and diseased, soil, water, air, &c. These different kinds of bacteria were distinguished by more or less well-marked characters, *e.g.*, the liquefaction or non-liquefaction of gelatin, the appearances of the growths in various culture media, the production of pigments, the pathogenic or non-pathogenic properties on different animals, whilst in some cases the ability

or inability to bring about certain chemical reactions was relied on as a means of diagnosis.

The more careful and prolonged study of individual kinds of bacteria by these methods has shown, however, that the differentiation between bacteria is a matter of even still greater difficulty than was hitherto supposed. Thus during recent years there are perhaps no two bacterial forms which have been so closely and carefully studied as Eberth-Gaffky's typhoid bacillus and Koch's cholera spirillum. The result of this concentrated study has been to reveal an ever-increasing number of forms, so closely allied to each that their differentiation becomes more and more difficult, and is based on more and more refined and artificial distinctions.

The extraordinary difficulty with which this branch of bacteriological practice is at present attended is well illustrated by the following remarks of M. Metchnikoff[1] on Dr. Koch's last paper on the subject of the diagnosis of the cholera bacillus:—

'The characters which were formerly regarded as specific to the comma bacillus, such as the form of the bacteria, their motility, the manner of their growth in gelatin, suffice no more. M. Koch himself describes a case of cholera in which the comma bacilli liquefied the gelatin so slightly that the colonies had the form of shields (*boucliers*). On the other hand, in the vibrio of Massowah (obtained in a cholera epidemic there) we have an example of a comma bacillus which liquefies the gelatin much more than the typical forms. On this account M. Koch now abandons as useless the stab-cultures in gelatin. The examination of drop-cultures becomes of similarly small importance, because it has been shown that indisputable comma bacilli can be completely deprived of motility, whilst other vibrios can be very motile.

'The form of the vibrios is again very variable. Besides the vibrios which are bent and thick, there are found forms which are slim and thin, sometimes hardly bent at all.'

But perhaps nothing shows the inadequacy of morphological methods alone for purposes of diagnosis more conspicuously than the recent investigations which have been made by those newly perfected modes of mordant staining devised by Loeffler, and by means of which some of the finest bacterial structures—the cilia or flagella—are rendered visible with a degree of precision hitherto unequalled. The observers who have hoped to establish a basis of differentiation on such minute microscopic distinctions as these beautiful staining methods reveal have had their hopes rudely shattered by the extraordinary variability which is exhibited by one and the same form in this respect.

This variability is most strikingly exhibited by the plates of Nicolle and Morax[2] of the cilia found on the cholera bacillus and its allies, as well as on the typhoid bacillus and bacillus coli communis: these plates show that there are as great differences in the number and arrangement of the cilia on cholera spirilla obtained from different sources as amongst spirilla generally acknowledged to be of different kinds. Thus practically all morphological distinctions, both micro- and macro-scopic, have had to be abandoned as a means of final diagnosis in the case of the cholera bacillus.

[1] 'Recherches sur le Choléra et les Vibrions,' *Ann. de l'Inst. Pasteur*, vii. (1893), p. 563.

[2] 'Technique de la Coloration des Cils,' Nicolle and Morax, *Ann. de l'Inst. Pasteur*, vii. (1893), p. 560.

To what tribunal must the bewildered bacteriologist have recourse? In Dr. Koch's last paper, 'Der augenblickliche Stand der Choleradiagnose' (*Zeitsch. f. Hygiene*, xiv. [1893], p. 335), the final referees in this diagnosis are (1) the so-called indol reaction and (2) the pathogenic effects of inoculation into animals. Thus the morphological have had to give way to chemical and physiological tests.

An almost precise parallel is presented by the history of the diagnosis of the typhoid bacillus. In the first instance morphological tests for its identification were in vogue, more especially its great motility in broth and its almost invisible growth on potatoes; both of these criteria have had to be abandoned, inasmuch as they are possessed also by closely allied organisms, and the tests which at present serve at any rate for its ready distinction from the bacillus coli communis are (1) the absence of indol reaction, (2) the non-coagulation of milk, and (3) the non-fermentation of dextrose and meat extract.

Thus, whilst morphological methods may serve to distinguish the typhoid bacilli from a number of other forms, it is to chemical tests that we must have recourse in order to differentiate it from its closest allies.

I do not, however, for a moment wish to convey the impression that such chemical tests are altogether unassailable—far from it, for I have had abundant opportunities of observing their inconstancy and treacherous variation. It is, however, highly significant that in the diagnosis of the two micro-organisms, upon which almost more attention has been recently showered than upon any others, the tests universally acknowledged to be the most reliable are in both cases chemical ones. It is, moreover, obvious that these chemical differences will in the future have to be far more closely and systematically studied than in the past, as they are doubtless capable of very great extension for purposes of diagnosis.

Thus, the only other chemical tests which have hitherto been in any way extensively introduced are—

(1) The reduction of nitrates to nitrites.
(2) The ammoniacal fermentation of urea.

Of these the first is particularly available, as a comparatively large number of bacteria have the power of effecting this change, whilst hitherto, curiously, only one organism has been found possessing the power of bringing about the oxidation of nitrites to nitrates.

Fermentations.—These chemical tests to which, as I have pointed out, we are now so often obliged to resort in bacteriological diagnosis naturally lead us to a consideration of some of the more striking chemical changes induced by micro-organisms, and which we generally group together under the name of Fermentations.

Of these fermentations the most important, from a practical point of view, is still, of course, the alcoholic fermentation induced by yeast, and, as is so well known, the practical application of this fermentation has been put on a sound scientific basis through the researches of Chr. Hansen, whose pure yeasts have, however, hitherto found less favour in this country than elsewhere, although they have been employed on a large experimental scale by Mr. Horace Brown and Dr. Morris, whilst more recently, in a few English breweries, the pure yeasts have been adopted to some extent in actual practice. The principal difficulty in the way of these pure yeasts being employed for English beers appears to be that, until recently, none of them was capable of bringing about that 'after-

fermentation' which is so essential to the 'conditioning' of the beer. Quite recently, however, this difficulty is said to have been overcome by Van Laer, who has succeeded in obtaining a yeast in a state of purity which is endowed with this power.

In this connection it is worthy of remark that, during the past year, there has been established, at Burton-on-Trent, 'The British Pure Yeast Company,' under the direction of Dr. Van Laer, from which it is hoped that the British breweries will be gradually induced to adopt the employment of pure yeast fermentations.

In his last publication Hansen ('Untersuchungen a. d. Praxis der Gärungsindustrie,' Munich and Leipzig, 1892) gives a list of the various breweries in which his method has been adopted, and of which the following table is a summary :—

BREWERIES USING HANSEN'S APPARATUS.

(1) *Bottom Fermentation.*

Denmark	7	Holland	4	N. America	10
Norway	4	Switzerland	1	S. America	13
Sweden	5	Finland	1	Australia	1
Germany	65	Russia	11	Japan	1
Austria	3	Poland	1	Manilla	1
France	2	Spain	1		

(2) *Top Fermentation.*

Denmark	3	Holland	2
Germany	2	Belgium	5
France	5	Finland	1

(3) *Distilleries and Pressed-yeast Manufactories.*

Denmark	1	Argentinia	1
Germany	1	Madras	1
France	1	Manilla	1
Russia	1		

Although in this table given by Hansen—he does not refer to any English breweries using his apparatus—he states that he believes there are now one or two in which it is beginning to be regularly employed.

Speaking of this country, Hansen says that English brewers were more disposed to talk than to experiment, and, after referring to the formation of the British Pure Yeast Company, he remarks that '*there is now a prospect of the new advance shortly taking root in the great conservative island-empire!*'

As regards the mechanism of the alcoholic fermentation of sugar, the ingenious theory of Pasteur, which ascribed it to the life of the yeast organism in the absence of oxygen, has now been generally abandoned; in fact, the recent experiments of Adrian Brown conclusively show that a given number of yeast-cells actually produce more alcohol when abundantly supplied with oxygen than when this gas is excluded. It has long been admitted that the vegetative activity of the yeast is increased by the access of oxygen, and with this increased activity its specific power of decomposing sugar is heightened also.

Of greater interest to the chemist than the ordinary alcoholic fermentation are those numerous and much more diversified fermentative

decompositions which are induced by bacteria, for the discovery of so many of which we are indebted to Pasteur and Fitz. The substances which have already been shown to be capable of undergoing fermentative change through the agency of bacterial life, although numerous, are practically confined to the carbohydrates, polyhydric alcohols, and oxy-acids.

Moreover, the products obtained in these numerous fermentations are, if we except comparatively minute traces, still more limited in number. The most common are—

Alcohols: Ethyl, butyl, amyl.
Polyhydric Alcohols: Mannitol.
Monobasic Acids: Formic, acetic, propionic, butyric, valerianic.
Oxyacids: Lactic.
Dibasic Acids: Succinic.
Gases: Carbonic anhydride, hydrogen, marsh gas.

In almost all cases the products formed in these fermentations are of simpler molecular structure than those from which they have been derived, the most conspicuous exception to this general rule being the fermentative synthesis of butyric from lactic acid.

In almost all cases, moreover, the fermentative decomposition includes a process of oxidation and reduction, one part of the original molecule being oxidised at the expense of the other. Thus, one of the commonest forms of fermentation is that in which a fatty acid and an alcohol, generally the one corresponding to the acid in question, are simultaneously produced.

Two questions naturally suggest themselves in connection with these bacterial decompositions:—(1) Does the same substance yield different products when fermented by different micro-organisms? (2) Does the same micro-organism produce the same products in the fermentation of different substances?

The first of these questions has been answered by the researches of Fitz, who found that one and the same substance was capable of yielding different fermentation products, according to the fermenting material employed. Nor is this result in any way modified by the fact that we have no guarantee that the ferments used by Fitz were pure cultivations; in fact, in many cases, they were admittedly mixtures.

On the other hand, the answer to the second question can obviously only be furnished by experiments made with pure cultures of fermenting organisms.

I have for some time past been conducting experiments on this subject, and, as far as these have yet proceeded—for they are necessarily of the most laborious character—they clearly show the most striking tendency for the products elaborated by one and the same organism from different fermentable substances to be the same. Thus I have shown that one and the same bacillus, operating on such different substances as dextrose, galactose, maltose, milk-sugar, mannitol, arabinose, glycerin, and glyceric acid, yields qualitatively the same products—viz., ethyl alcohol, acetic and formic acids (traces of succinic acid), carbonic anhydride, and hydrogen.

Similar results have more recently been obtained by Grimbert, who has studied the fermentation induced in starch, inulin, dextrose, maltose, cane-sugar, invert-sugar, milk-sugar, arabinose, mannitol, and glycerin

by the *B. orthobutylicus*, and has found that in all cases the products were qualitatively the same—viz., acetic and butyric acids, normal butylalcohol, carbonic anhydride, and hydrogen.

I do not, however, for a moment suppose it likely that one and the same organism will decompose *all* substances, so as to form the same products; but it is sufficiently remarkable that the same products should be obtained from such comparatively different parent substances, a phenomenon which is most probably explicable by the assumption that the several substances are, in the first instance, broken down into some intermediate substance which then undergoes further transformation.

Thus, probably the fermentability of bodies depends upon their being able to yield such intermediate substances with facility. A substance that doubtless plays an important part as an intermediary in such fermentation decompositions is lactic acid, which is known, indeed, to be capable of yielding a number of different products under bacterial action—*e.g.*, valerianic, butyric, propionic, and acetic acids, besides butyl and ethyl alcohols. In this connection it is worthy of note also that the only sugars which are capable of undergoing fermentation by yeast are those which contain three or some multiple of three atoms of carbon in the molecule; moreover, even towards the bacterial ferments, with their more catholic tastes, the carbon compounds containing such a tri-carbon nucleus appear to offer peculiar facilities for attack. That intermediate reactions of various degrees of complexity take place in these fermentative decompositions again is shown by the several kinds of lactic fermentation, to which I will refer presently.

In these fermentation phenomena formic acid appears to play a very important part; the presence of this substance among fermentation products has been observed by a number of investigators. It is frequently mentioned as occurring, generally in small quantities, by Fitz, and similarly by Grimbert, in the butyric fermentations, to which I have already referred. In my experiments, however, I have found that the amount of this formic acid may be very greatly increased by special conditions. Thus in those fermentations conducted in flasks closed only with cotton-wool plugs the proportion of formic acid was generally only very insignificant, whilst in the case of fermentations carried on in closed vessels provided only with a delivery-tube dipping under mercury for collecting the evolved gases the proportion of formic acid produced was invariably very considerable; and, further, in these closed fermentations in which the gases were collected I have always found that the carbonic anhydride and hydrogen were evolved in approximately the proportions in which they are present in formic acid—viz., equal volumes. In these closed fermentations it was, moreover, found that the fermentation was less complete than in the flasks plugged with cotton-wool only. Now it has been shown by Duclaux ('Annales de l'Inst. Pasteur,' vi. [1892], 598) that free formic acid is a powerful antiseptic, and it is highly probable, therefore, that the production of this formic acid in the closed fermentations is the cause of their being prematurely arrested by this toxic product. Whether the formic acid is not produced at all when the fermentation takes place in the open flask, or whether the organism is capable of decomposing it in the presence of air under these circumstances, I have not yet determined. Duclaux (*loc. cit.*) has shown that moulds are capable of destroying free formic acid in the presence of air; but the action of

moulds when growing superficially on organic liquids is, so far as we know, entirely different from that of bacteria, inasmuch as the moulds simply convert the organic elements into their ultimate products of oxidation, and do not excite fermentations in the stricter sense of the word.

Recent Additions to Knowledge of Lactic Fermentation.—The lactic fermentation, which was one of the earliest-known fermentations, and with the investigation of which the names of Pasteur and Lister are associated, has recently formed the subject of some researches, which appear to me to be of particular interest from a chemical point of view. In the ordinary lactic fermentation, as is well known, the lactic acid obtained is inactive, irrespectively of whether it is derived from starch, milk-sugar, cane-sugar, dextrose, or mannitol. By employing different lactic fermentation bacteria, however, both the active lactic acids have been obtained by direct fermentation. Thus Nencki and Sieber ('Berlin. Berichte,' xxii. c. 695) have discovered a lactic ferment which yields sarcolactic acid (*i.e.*, dextro-rotary lactic acid) in the fermentation of dextrose; whilst Schardinger ('Chem. Soc. Journ.,' Abstr., 1891, p. 666) has described the production of lævo-rotary lactic acid in the fermentation of cane-sugar. How are these three different lactic fermentations to be interpreted by the light of our present knowledge of the constitution of the sugar molecules, which is based on those researches of Emil Fischer, which have excited such profound and widespread admiration?

Taking the now generally accepted constitutional formulæ of dextrose, lævulose, and mannitol—

$$
\text{Dextrose}\ \begin{array}{l} CH_2OH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ -CHOH \\ | \\ COH \end{array}
\qquad
\text{Lævulose}\ \begin{array}{l} CH_2OH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ CO \\ | \\ CH_2OH \end{array}
\qquad
\text{Mannitol}\ \begin{array}{l} CH_2OH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ +CHOH \\ | \\ CH_2OH \end{array}
$$

in which the several asymmetric carbon atoms are indicated by the signs + or − according to the relative arrangement of the groups around them. It is easy to see how the carbon-skeleton of dextrose can yield by simple decompositions, in which the terminal groups—COH or CH_2OH—are converted into COOH, either the dextro- or the lævo-rotary lactic acid, according to the particular asymmetric carbon atom in the dextrose which is made to form the asymmetric carbon atom in the lactic acid, thus:—

$$
\begin{array}{l} CH_3 \\ | \\ -CHOH \\ | \\ COOH \end{array}
\qquad\qquad
\begin{array}{l} CH_3 \\ | \\ +CHOH \\ | \\ COOH \end{array}
$$

Lævo-rotary lactic acid.   Dextro-rotary lactic acid.

Again, by such simple decomposition, the lævulose molecule should only be capable of yielding the dextro-rotary lactic acid; and similarly the mannitol molecule should only be capable of yielding the dextro-rotary lactic acid; for it is obvious, again, that, if the terminal groups

only are converted into COOH, the resulting lactic acid will have its asymmetric carbon atom, with the sign + before it. It is unnecessary to point out that all these signs may also be directly opposite to the actually observed rotation, so that the speculation may be more correctly and briefly summarised in the words, that *whilst both active lactic acids are theoretically obtainable by the simplest decomposition of dextrose, only one and the same of the two active isomers should be similarly obtainable from either lævulose or mannitol.*

On the other hand, it is equally obvious that in order to obtain inactive lactic acid from any of the above molecules it is necessary either that there should be an intermediate product formed in which the asymmetric carbon atom of the ultimate lactic acid has lost its asymmetry, or that the two active lactic acids should be formed in exactly equal molecular proportions, and thus destroy the rotatory power. On the latter supposition, inactive lactic acid should only be readily obtainable from dextrose, as neither the lævulose nor the mannitol molecules are theoretically capable of yielding, *by simple conversion*, more than one of the isomeric active lactic acids, but it is experimentally certain that inactive lactic acid can be obtained by the fermentation of pure mannitol.

In these decompositions effected by micro-organisms a remarkable feature is not unfrequently observed which must be of great significance, both from a chemical and biological point of view—I refer to the phenomenon of *selective or preference fermentation.* This phenomenon was first observed by Pasteur ('Jahresbericht d. Chem.,' 1860, p. 250; 'Comptes Rendus,' xlvi. p. 615) in the case of tartaric acid, who found that both bacteria and moulds attacked the dextro-rotary modification by preference; similarly, Lewkowitsch ('Berlin. Berichte,' 1883, pp. 1568, 2722) found that in the case of mandelic acid the lævo-rotary isomer is first destroyed by the mould *Penicillium glaucum.* More recently I have shown that by the fermentative action of the *Bacillus ethaceticus* on glyceric acid the lævo-rotary acid is first decomposed, obtaining in this manner a dextro-rotary glyceric acid, which is of particular interest and value, inasmuch as it is the simplest active acid which can be obtained in practically unlimited quantity, and by means of which the laws regulating the rotatory power of active bodies in general can be investigated in their simplest form. Of this new substance no less than twenty active derivatives have already been prepared in my laboratory, and have served to throw light on the more recent speculations concerning the peculiarly fascinating subject of the asymmetric carbon atom. Still more recently I have obtained by this selective fermentation the dextro-rotary lactic or sarcolactic acid, which, although long known, has hitherto been only obtainable with great difficulty. I hope, however, by this means to render it as accessible as the dextro-rotary glyceric acid, and the study of its derivatives, which are as yet almost wholly unexplored, should also furnish important data for stereo-chemical theory.

The cause of this remarkable phenomenon of selective fermentation is at present wholly wrapped in obscurity, but I would venture to suggest that it is to be sought for in the differences which such optical isomers only unfold when they are combined with other active bodies. Thus, when the optically isomeric tartaric acids are combined with the optically active base cinchonine, for instance, the resulting cinchonine dextro- and lævo-tartrate exhibit marked differences of solubility from each other. Is it not highly probable that optically active substances which are invariably

present in living cells may enter into combination with these optically active fermentable isomers, and by thus establishing differences—*e.g.*, of solubility—between them render one of them—probably the more soluble one—more accessible to the specific decomposing influence of the cell-protoplasm?

Whether in such selective fermentations it is invariably the same optical isomer or not that first disappears under the influence of vital decomposition has not been with certainty ascertained. Pasteur, however, found that it was the dextro-tartaric acid which was first destroyed, irrespectively of whether a bacterial fermentation or a mould combustion was employed. Similarly, in the case of lactic acid, it was the lævo-rotary acid which first disappeared in my bacterial fermentation, already referred to, as well as in the mould combustion of lactic acid, studied by Linossier ('Berlin. Berichte,' xxiv. c. 660). On the other hand, Lewkowitsch (*loc. cit.*) records the preferential decomposition of one optically isomeric mandelic acid by the mould *Penicillium glaucum*, and of the opposite isomer by a bacterial ferment. As this is, so far as I am aware, the only instance of the kind, it is highly desirable that it should be reinvestigated, and either confirmed or disproved.

It must not be supposed that in this selective fermentation one of the isomers is necessarily quite unfermentable, for, as far as this matter has been carefully investigated, it would appear to be only that one of the isomers is relatively less fermentable than the other. Thus in the fermentation of lactic acid, which I have recently studied, I found that if the fermentation was allowed to finish the whole of the lactic acid was broken up into other products; but if arrested at an intermediate stage the lactic acid remaining undecomposed always contained sarcolactic acid, showing that the lævo-rotary lactic acid had been decomposed by preference.

In the fermentation of glyceric acid the selective phenomena are extremely remarkable. Thus when I first isolated the *Bacillus ethaceticus* some years ago I found that its powers of fermenting glyceric acid in the form of calcium glycerate were very feeble, and that even when the fermentation was allowed to complete itself practically the whole of the dextro-rotary glyceric acid remained untouched by the bacillus. But on continuously cultivating this bacillus in solutions of calcium glycerate I found that its power of decomposing this substance was becoming markedly greater; thus, not only did the fermentations last longer, but the proportions of undecomposed dextro-rotary glyceric acid remaining at the end of the fermentations became less and less. In order, therefore, to obtain a satisfactory yield of the residual active glyceric acid, it now becomes necessary to arrest the fermentation, and thus save the dextro-glyceric acid from destruction. We can also still obtain a satisfactory yield of the active glyceric acid by using for the fermentation ethacetic bacilli which have hitherto been strangers to solutions of glyceric acid; these bacilli then only decompose the lævo-glyceric acid, the dextro-glyceric acid molecules being untouched by them. In fact, in this manner the fermentative activity of this *Bacillus ethaceticus* can be regulated with the greatest nicety and precision, and this forms a good example of the profound modifications which can be effected in micro-organisms by what may be called *educational culture.*

Modifications effected in Micro-organisms by Educational Culture.—This subject of the modification of micro-organisms by artificial means is

of such far-reaching importance that I must ask you to permit me to devote a little further attention to it. There are an immense number of isolated and incidental observations concerning such induced modifications distributed through bacteriological literature, but there are comparatively few connected researches which have been made with the object of deliberately ascertaining what are the limits within which such modifications can be made.[1]

That bacteria are peculiarly liable to present the most extraordinary changes in form was demonstrated already twenty years ago by Professor Ray Lankester's observations on the *Beggiatoa roseo-persicina* ('Quart. Journ. Mic. Sci.,' xiii. 1873), whilst during recent years the examples of variation, both in form and function, which have been observed are so numerous that even a mere enumeration of them would involve more time than I have at my disposal. It is not, however, perhaps out of place to give those of you who are less familiar with this subject an instance of the profound morphological change which can be impressed on a micro-organism by artificial means. To my mind perhaps the most striking instance of this kind is the artificial production by Chamberland and Roux of a variety of anthrax bacilli, which are incapable of producing spores under any known conditions whatsoever. This fundamental metamorphosis in the morphology and physiology of the organism is effected by cultivating the ordinary anthrax bacilli in broth, to which a small proportion of potassium dichromate ($\frac{1}{2000}$), or phenol (about $\frac{6}{10000}$) has been added. This sporeless, or *asporogene*, anthrax is equally virulent, and in all respects resembles the ordinary anthrax bacilli, excepting in the particular of inability to form spores. This peculiarity is, moreover, so permanently stamped upon it that it persists even after passing the asporogene bacillus through the bodies of animals.

I ought also to mention similarly profound and permanent morphological changes which Hansen has made in yeasts by prolonged culture in aërated wort near the maximum temperature. In this manner yeast varieties were obtained which had entirely lost their power of producing spores under whatever conditions they might subsequently be cultivated (Hansen, 'Centralbl. f. Bakteriol.,' vii. [1890], p. 795).

Equally striking are the changes in the functions of bacteria which can be artificially produced.

Into the artificial and permanent diminution of the virulence of pathogenic micro-organisms it is not necessary for me to enter, as the production of attenuated viruses or vaccines for the purposes of preventive inoculation is already carried out on what may be called an industrial scale. But the converse operation may also be effected, that is to say, an organism possessing only a low degree of virulence may by artificial means have its virulence increased beyond that which it normally exhibits in nature. This has been done by Malm, for the bacillus of anthrax, by passing this organism through animals which, like the dog, are naturally very refractory to this disease, or which have been rendered artificially refractory by vaccination ('Ann. de l'Inst. Pasteur,' vii. [1890], p. 532). Hitherto, however, such increased virulence has not been

[1] A useful summary of the principal instances of recorded variations amongst bacteria, more especially those of a pathogenic nature, was contributed to the Pathological Section of the meeting of the British Medical Association, held at Nottingham in July of last year, by Professor Adami (*Medical Chronicle*, September, 1892).

imparted to bacteria by more purely artificial means, *e.g.*, by subjecting them to chemical treatment, nor has it yet been found possible to convert a perfectly harmless micro-organism into a pathogenic one.

Instances of artificially induced changes of bacterial function, other than pathogeneity, are far more easy to study with accuracy and precision as the complicating differences of animal organisation are eliminated. Thus, whilst any two animals selected for experiment must necessarily differ in more or less important respects, any number of test-tubes containing a culture medium of precisely the same composition can be prepared.

Changes of Function.—Everyone who has cultivated bacteria over long periods of time will probably have noticed more or less conspicuous changes in some of their functional activities, *e.g.*, that the power of liquefying gelatin, possessed by some, has become diminished, or that the power of producing pigments has become impaired, or perhaps has actually disappeared altogether. Or, again, it may frequently be observed that an organism which had originally the power of fermenting some particular substance has lost this power through prolonged culture, and, indeed, even a single passage through gelatin may sometimes apparently destroy the capacity to exercise this function. Thus, I have in my possession a bacillus which has the power of fermenting calcium citrate, and this function it continues to exercise for years if grown in suitable media. On submitting such a fermenting solution of calcium citrate to plate cultivation, colonies make their appearance in due course; but on transferring one of the colonies to a sterile solution of calcium citrate it invariably fails to set up a fermentation, the bacillus having by mere passage through the gelatin-medium lost its fermenting power. If, however, a similar colony be put into broth containing calcium citrate the latter is readily fermented; on now inoculating from this to a weaker broth containing calcium citrate this also is put into fermentation, and by successively passing in this manner to weaker and weaker broths containing calcium citrate we may ultimately set up fermentation in a calcium citrate solution which was absolutely unfermentable when the bacilli were taken directly from the gelatin plate ('Micro-organisms in their Relation to Chemical Change,' Royal Institution, 1892).

A striking example of permanent loss of function is described by Laurent ('Ann. de l'Inst. Pasteur,' iv. [1890], p. 465) in the case of the *Bacillus ruber* of Kiel; an organism which, as its name implies, produces a red pigment. Laurent found that if cultures of this bacillus were exposed to bright sunlight for a period of three hours the subsequent cultures were almost invariably colourless, and so permanent was this loss of pigment-producing power that thirty-two successive cultures, carried on over a period of a year, failed to restore it.

If such numerous bacterial varieties can be artificially induced in the laboratory, it is surely highly probable, in fact all but certain, that similar modifications have been, and are still, continually arising amongst the bacteria growing amidst natural surroundings This anticipation is fully borne out by the direct examination of the bacterial forms occurring in nature. It is a most striking and significant fact that in the case of almost any micro-organism which has received special attention on account of some particular property which it possesses, *e.g.*, pathogenic power, a careful examination of the natural habitat of such an organism has almost invariably led to the discovery of one and often many other

bacteria resembling the particular one in question in almost every respect, but differing in one or more details—certainly not more important details than those which we have seen can be artificially produced in the laboratory. Let me cite a few examples of such natural varieties, as we may call them.

The *bacillus of anthrax* we know under natural conditions may, and frequently does, temporarily reside in the soil; it would not be surprising, therefore, to find in the soil some organism presenting more or less likeness to this bacillus. As a matter of fact, not only has an organism indistinguishable from anthrax in all save its pathogenic properties been discovered in the soil by Hueppe and Cartwright Wood, but these investigators further proved the excessively close relationship of this soil bacillus to the anthrax bacillus by the observation that rabbits and even mice inoculated with the soil bacillus were protected against subsequent inoculation with virulent anthrax, as though they had been vaccinated with an attenuated anthrax virus ('Lancet,' February, 1889; 'Berlin. klin. Wochenschrift,' No. 16, 1889).

The *diphtheria bacillus* of Loeffler ('Centralbl. f. Bakteriol.,' ii. [1887], p. 105) was found by him in the false membranes of the throat *associated with* another bacillus, almost indistinguishable from it, excepting that it had no toxic effect on animals. Roux and Yersin ('Ann. de l'Inst. Pasteur,' iv. [1890], p. 385) have, moreover, found that this *Bacillus pseudo-diphthericus*, as it is called, is frequently present in the pharyngeal mucous membrane of healthy children.

The *cholera bacillus* of Koch, again, as we have already seen, is not only subject to very considerable variations in form and functions according to the particular place or epidemic from which it has been obtained, but its natural habitats—the human intestine and natural waters—have both been found to yield forms which are distinguishable from it only with the greatest difficulty.

The *typhoid bacillus* of Eberth-Gaffky, again, is distinguishable only with the greatest difficulty from a number of pseudo-forms occurring in its natural habitats—the human intestine and natural waters.

Closely connected with these phenomena are doubtless also *aërobic* and *anaërobic growth*. As is well known, bacteria may be divided into three classes, according to their relationship to oxygen :—

(1) Compulsorily aërobic, or those organisms which will only grow in the presence of free oxygen; (2) facultatively aërobic and anaërobic, or those organisms which can grow either in the presence or absence of free oxygen; (3) compulsorily anaërobic, or those organisms which will only grow in the absence of free oxygen. The phenomenon of aërobic growth would appear, of course, to be the normal one; but in many of the decompositions brought about by bacteria such large quantities of gases—especially carbonic anhydride and hydrogen—are evolved that all free oxygen is rapidly swept out of the medium in which the bacteria are carrying on their operations. Under these circumstances, then, any bacteria which are entirely dependent on oxygen would have their vitality either destroyed or suspended, whilst those which can maintain themselves either temporarily or permanently in the absence of oxygen must be at a great advantage, inasmuch as they can continue their vital processes in the oxygen-deprived medium which they have themselves created. In this way we can imagine how originally aërobic organisms endowed with the capacity of decomposing certain substances with the

evolution of gases (CO_2, H, &c.) have gradually become modified so as to endure for longer and longer periods of time the exclusion of oxygen; and finally some forms have become so far modified as to only find the means of livelihood in the entire absence of oxygen, or, in other words, they have become obligatorily anaërobic.

Thus, whilst Pasteur ascribes fermentation to the life of micro-organisms in the absence of oxygen, it appears to me that the life of micro-organisms in the absence of oxygen is necessitated by their power of bringing about fermentative changes which banish oxygen from the medium; in fact, the fermentative capacity is probably antecedent to the anaërobic capacity.

Direct experiments as to how far aërobic micro-organisms can be trained to thrive in the absence of oxygen, and *vice versâ*, are urgently wanted; but there is already sufficient evidence that fermentative capacity is not dependent on absence of oxygen. I have already referred to this subject in connection with yeast fermentation, but it is equally true of bacterial fermentations also; thus my *Bacillus ethaceticus* ferments most vigorously in the presence of air, but it would, of course, not be a fermenting organism in the commonly accepted sense of the word if it could not also ferment in the absence of air, because in ordinary fermentations, as there is no provision made for the continuous supply of air, if the organism were obligatorily aërobic, the fermentation would at once cease as soon as the oxygen initially present was used up.

These views are moreover in entire harmony with the observations of other investigators concerning fermentation bacteria. Thus amongst the most obligatorily anaërobic organisms with which we are acquainted is the common butyric ferment, the so-called *Bacillus amylobacter*, which can only be cultivated in the entire absence of oxygen. It must not, however, be imagined that the butyric fermentation is dependent upon the absence of oxygen, for Hueppe has isolated and described a bacillus which, whilst bringing about the same butyric fermentations as the *B. amylobacter*, is aërobic. Of the primitive bacteria possessing the power of exciting butyric fermentation we must conclude, therefore, that the ancestors of the *B. amylobacter* became so far modified by long-continued residence amidst anaërobic surroundings as to have *apparently* lost the power of aërobic growth altogether, whilst the ancestors of Hueppe's butyric bacillus, having undergone less specialisation, can still flourish either in the presence or absence of air.

These instances which I have selected are only a few out of a large number of similar cases which are recorded in literature, but they are sufficient surely for anyone whose mind is not burdened and biassed by preconceived ideas concerning species to draw their conclusions as to the mutability of bacteria, whilst they show the rare opportunities which are afforded by these micro-organisms for experimentally studying some of the phenomena of evolution.

Sanitary Aspects of Bacteriology.—The advances in bacteriology which have probably excited most general interest are those which have reference to the maintenance of the public health; the bacteriology of air, water, soil, and articles of diet, disinfection, and the like. It would be impossible for me in the time which is available to present to you even the merest outline sketch of the enormous amount of work which has been done during recent years in this department. I will confine myself to a few points which appear to me to be of more particular interest to

chemists. Thus the investigation of numerous hygienic questions, more especially relating to water supply and sewage disposal, forms a very important part of professional chemistry, and the bearing of recent bacteriological research on these questions must of necessity, therefore, be of peculiar interest to many chemists. When the bacteriological examination of water first came into vogue some eight or nine years ago there was a general impression amongst enthusiasts for the new science that it would, in a very short time, entirely supersede the chemical examination owing to the inability of the latter to distinguish between dead and living organic matter, and to reveal the presence of disease-producing organisms. From the newly established bacteriological laboratories on the Continent there emanated in rapid succession publications in which standards of bacteriological purity for water were hastily set up by men who, whilst doubtless very skilful bacteriologists, were quite ignorant of the subject of water supply, with its numerous complicating factors. It is quite unnecessary for me to enter into a discussion of these standards of purity, because happily they have been banished from the vocabulary of those who have had any considerable experience in these matters.

Many persons, again, have been, and are still, under the impression that the main object of an examination of water is to ascertain whether it contains materials capable of causing disease, and that the inability of chemical analysis to answer this question proves its inutility. The absurdity of this view is so manifest, and the misconception to which it is due so obvious, that its wide prevalence is my only excuse for referring to it. A water examination which only reveals the unsuitability of the water when disease germs are actually present in it can surely be of little value indeed, inasmuch as the mischief will in all probability have been already done before the examination has been made or thought of. The object of a water examination should obviously be to ascertain whether a water is liable to be a source of danger, and not whether it is actually dangerous at the moment of examination. Now I have no hesitation in saying, and I have frequently expressed it as my opinion during this controversy, that a proper chemical analysis is able to throw more important light on this question than a bacteriological examination.

On the other hand, I have from the very first turned to bacteriology for an answer to some questions concerning the hygienic aspects of water, which I am equally strongly of opinion cannot be answered by chemical methods of examination at all. Already in 1885 I pointed out in a paper to the Royal Society, 'On the Removal of Micro-organisms from Water,' and elsewhere how the then recently introduced methods of bacteriological research enabled us for the first time to ascertain the real hygienic value of methods of water purification, both artificial and natural, such as sand filtration, subsidence, precipitation as in Clark's process, natural filtration through porous strata, &c.

Thus I showed that the improvements effected in the quality of water by sand filtration, by Clark's process, and by subsidence are quite insignificant—from a chemical point of view—as compared with their bacteriological efficiency. The bacteriological effect of these processes may be illustrated by means of the following tables summarising some of my results.

Thus the first two tables show the remarkable efficiency of sand-filtration in removing micro-organisms from water:—

1886.—*Number of Micro-organisms in 1 c.c. of River Thames Water before and after Filtration.* (PERCY FRANKLAND.)[1]

DESCRIPTION OF WATER.

—	Unfiltered	Chelsea	West Middlesex	Southwark	Grand Junction	Lambeth
January	45,400	159	180	2,270	4,894	2,587
February	15,800	305	80	284	208	265
March	11,415	299	175	1,562	379	287
April	12,250	94	47	77	115	209
May	4,800	59	19	29	51	136
June	8,300	60	145	94	17	129
July	3,000	59	45	380	14	155
August	6,100	303	25	60	12	1,415
September	8,400	87	27	49	17	59
October	8,600	34	22	61	77	45
November	56,000	65	47	321	80	108
December	63,000	222	2,000	1,100	1,700	305
Average for year	20,255	146	234	524	630	475

1886.—*Percentage Reduction in the Number of Micro-organisms present in the River Waters before delivery by the Companies.*

DESCRIPTION OF WATER.

—	Chelsea	West Middlesex	Southwark	Grand Junction	Lambeth
January	99·7	99·6	95·0	89·2	94·3
February	98·1	99·5	98·2	98·7	98·3
March	97·4	98·5	86·3	96·7	97·5
April	99·2	99·6	99·4	99·1	98·3
May	98·8	99·6	99·4	98·9	97·2
June	99·3	98·3	98·9	99·8	98·5
July	98·0	98·5	87·3	99·5	94·8
August	95·0	99·6	99·0	99·8	76·8
September	99·0	99·7	99·4	99·8	99·3
October	99·6	99·7	99·3	99·1	99·5
November	99·9	99·9	99·4	99·9	99·8
December	99·7	96·8	98·3	97·3	99·5
Average reduction	98·6	99·1	96·7	98·2	96·2

In the following table are recorded the results obtained in two experiments, made in 1885, on the softening of water by Clark's process on the large scale:—

Number of Micro-organisms in 1 c.c. of Water. (PERCY FRANKLAND.)

Unsoftened deep well water obtained from chalk	322
Unsoftened deep well water obtained from chalk after softening by Clark's process	4
Reduction = 99 per cent.	
Unsoftened deep well water obtained from chalk	182
Unsoftened deep well water obtained from chalk after softening	4
Reduction = 98 per cent.	

The following table exhibits the remarkable manner in which bacteria

[1] Taken from the monthly reports presented to the Local Government Board for the year 1886.

in water are carried down and removed from suspension by the subsidence of solid particles of different kinds :—

Removal of Micro-organisms by Sedimentation. (PERCY FRANKLAND.)

Agitation for 15 *minutes with Chalk.*

Untreated water contained	8,000 in 1 c.c.
After agitation	270 in 1 c.c.
Reduction = 97 per cent.	

Agitation for 15 *minutes with Coke.*

Untreated water contained	Innumerable
After agitation	None
Reduction = 100 per cent.	

Agitation for 15 *minutes with Animal Charcoal.*

Untreated water contained	8,000 in 1 c.c.
After agitation	60 in 1 c.c.
Reduction = 99 per cent.	

Agitation for 15 *minutes with Vegetable Charcoal.*

Untreated water contained	3,000 in 1 c.c.
After agitation	120 in 1 c.c.
Reduction = 96 per cent.	

I have recently extended these observations to the subsidence of bacteria in water during storage in large reservoirs.

Reduction in number of Micro-organisms effected by storage of Water in Reservoirs. (PERCY FRANKLAND.)

New River Company.

Water in cutting above reservoir	677 in 1 c.c.
Water at outlet of first reservoir	560 in 1 c.c.
Water at outlet of second reservoir	183 in 1 c.c.

West Middlesex Company.

Thames water from Hampton	1,437 in 1 c.c.
Thames water from Hampton after passing through one storage reservoir	318 in 1 c.c.
Thames water from Hampton after passing through two storage reservoirs	177 in 1 c.c.

The above figures show the importance of storage as a means of removing bacteria from surface waters.

Another important matter, again, in connection with the hygiene of water, on which bacteriology alone can throw light, is the fate of pathogenic bacteria gaining access to water. This inquiry has been pursued by a number of investigators, and has led to many interesting results. Amongst the most important of these I may specially mention—

(1) That in some exceptional cases pathogenic bacteria are destroyed with remarkable rapidity, in a few hours, when introduced into ordinary potable water.

(2) That in the majority of cases they can retain their vitality and virulence in potable waters for considerable periods of time—days, weeks, and in the spore form for months or even years—but that their longevity is almost invariably, and often very greatly, curtailed by the common bacteria present in all natural waters. They are thus generally far more persistent when introduced into sterilised than into unsterilised water.

(3) With few exceptions the pathogenic bacteria which have been experimented with do not undergo any extensive multiplication in potable waters, although such multiplication is frequent in the case of foul waters like sewage.

Bacteriological examination, again, has greatly fortified the now generally accepted views as to the communication of typhoid fever and Asiatic cholera through the medium of drinking water by the actual discovery of the typhoid and cholera bacilli in waters which had been suspected of distributing these diseases.

It is precisely in this particular of bacteriological water examination that great advances have been recently made. The searching for pathogenic bacteria in a potable water must always be very much like looking for a needle in a haystack, and it has been abundantly shown that the ordinary process of plate-cultivation is, excepting in rare cases, quite inadequate for this quest, owing to the crowding out of the few pathogenic by the overwhelming majority of non-pathogenic forms. It has, in fact, become more and more evident that, in order to discover any particular organism—pathogenic or otherwise, for the matter of that—which is present in a very small minority, it is necessary to submit the water or other material under examination to a preliminary treatment before proceeding to plate-cultivation. This preliminary treatment must be so conceived and executed as to foster the multiplication of the particular organism of which we are in quest relatively to that of those organisms which are of no interest, and thus secure a majority of the former at the ensuing plate-cultivation, when no difficulty will arise in detecting its presence. Such special methods of examination are now in constant use for the detection of both the cholera and typhoid bacilli in water.

It will thus be seen that by combining chemical and bacteriological methods of examination our knowledge of water hygiene has been very greatly extended during recent years.

In the matter of sewage treatment the most laborious investigations, in which both chemical and bacteriological methods of examination were simultaneously employed, have been made by the Massachusetts Board of Health. The results of these investigations show, as would indeed be expected, that intermittent filtration through soil, if properly carried out, is the most efficient not only from a chemical but also from a bacteriological point of view, and in the chemical precipitation of sewage there is, in general, a much greater removal of micro-organisms than of organic matter, or, in other words, the bacteriological efficiency of these precipitation processes is generally much greater than their chemical efficiency.

Bactericidal Action of Light.—Although I have not time to enter into the subject of disinfection in its entirety—*i.e.*, the destruction of bacteria by chemicals and other agencies—there is a section of this subject on which I should not omit to say a few words, viz., the disinfecting or bactericidal action of light.

Very soon after bacteria had been introduced to the general public

through the earlier researches of Pasteur, Lister, Burdon Sanderson, and Tyndall, now about a quarter of a century ago, the important discovery was made by Downes and Blunt that these minute organisms were remarkably susceptible to direct sunshine.[1] Notwithstanding the novelty of the subject and the peculiar difficulties which then attended such researches, these two investigators worked out their discovery in such a very complete manner that I am of opinion it should be regarded as one of the most important additions made to the subject of bacteriology prior to the introduction of the more modern methods of studying bacteria. They clearly showed that this bactericidal action of sunlight is independent of any rise in temperature; that they are the rays at the blue end of the spectrum which are the most effective, the red rays being almost quite inert; further, that the action is highly favoured if not entirely dependent on the simultaneous presence of oxygen. Again, they showed that the action was quite independent of the presence of any culture medium, for if bacteria which had been suspended in distilled water were allowed to become air-dry on glass they were destroyed by subsequent insolation. Again, they found that the culture media which they employed (Pasteur solution) were not rendered unfit by insolation for the subsequent cultivation of micro-organisms. Another highly important point to which they drew attention was that the action of sunlight is much less effective if the bacteria are suspended in water than if they are present in culture solutions. They further showed that mould and yeast forms were less susceptible to light than bacteria, and they even extended their investigations to the soluble ferment invertase, the activity of which they also found succumbed to insolation. These classical investigations have been confirmed in practically every detail by the subsequent researches made with pure cultures of particular bacteria by Duclaux,[2] Arloing,[3] Straus,[4] Roux,[5] Gaillard,[6] Uffelmann,[7] Panzini,[8] Laurent,[9] Santorini,[10] Janowski,[11] Geisler,[12] Kotljar,[13] Buchner,[14] Momont,[15] Marshall Ward, and myself.[16]

Of special interest in connection with this subject are some recent experiments by Richardson,[17] who shows that when urine is exposed to direct sunshine peroxide of hydrogen is formed, the presence of which prevents the development of growths. There are several very interesting and important points arising out of this investigation:—

1. There can be no doubt that peroxide of hydrogen was formed in

[1] *Proceedings Royal Society*, 1877 and 1878.
[2] *Comptes Rendus*, c. and ci. (1885).
[3] *Ibid.*, c. p. 378; ci. p. 511; civ. p. 701; *Archives de Physiol. norm. et Path.*, vii. (1886), p. 209.
[4] *Société de Biologie*, 1886, p. 473.
[5] *Annales de l'Inst. Pasteur*, i. (1887), p. 445.
[6] *De l'Influence de la Lumière sur les Micro-organismes*, Lyons, 1888.
[7] *Die hygienische Bedeutung des Sonnenlichtes*, 1889.
[8] *Rivista d'Igiene*, 1889.
[9] *Ann. de l'Inst. Pasteur*, iv. (1890), p. 478.
[10] *Bull. della Accad. Med. di Roma*, xvi. (1889-90).
[11] *Centralbl. f. Bakteriologie*, viii. (1890), pp. 167, 193, 230, 262.
[12] *Ibid.*, xi. (1892), p. 161.
[13] *Ibid.*, xii. (1892), p. 836.
[14] *Ibid.*, xi. p. 781; xii. p. 217.
[15] *Ann. de l'Inst. Pasteur*, vi. (1892), p. 21.
[16] *Proc. Roy. Soc.*, 1893.
[17] *Trans. Chem. Soc.*, 1893.

Richardson's culture medium (urine) during insolation, and that this insolated urine possessed antiseptic properties. In this respect Richardson's experiments confirm certain previous observations made by Roux, but are in opposition to those of all other investigators who have devoted attention to this point. Thus Roux found that by the insolation of broth in the presence of air it became unfit for the germination of anthrax spores. Several other investigators, including Panzini and Janowski, have repeated this experiment with different culture materials, but have failed to confirm it. Roux's results were, however, so very definite that it has always seemed to me impossible to doubt their accuracy, and I have attributed the discrepancy between his results and those of others to some difference in the conditions under which the experiments were made. The definite proof which has now been furnished by Richardson that peroxide of hydrogen is formed in some culture media by insolation, and that the conditions necessary for the formation and preservation of this antiseptic substance are by no means perfectly understood, clearly shows that Roux and his opponents may both be right, and that the different results arrived at depend upon differences in the conditions under which the experiments were carried out, the nature of which differences is at present not understood. That Roux's insolated broth was rendered unfit for the germination of anthrax spores by the presence of peroxide of hydrogen is almost certain also from the fact that he found such insolated broth to recover its original nutritive properties if it was kept in the dark or in diffused daylight for a certain length of time.

2. The proof of the formation of peroxide of hydrogen during insolation naturally suggests the question whether the whole bactericidal effect of light is due to this material, or whether it only partially accounts for the phenomenon. This important question is one which it is far from easy to answer owing to the almost insuperable difficulty of securing conditions under which the generation of peroxide of hydrogen is impossible. We will examine some of the experiments which bear on this point:—

(*a*) Downes and Blunt found that germs which had been *air-dried* on glass were destroyed by subsequent insolation.

(*b*) Momont found that anthrax spores *dried for twelve hours by means of a sulphuric acid vacuum* subsequently withstood insolation for upwards of 100 hours.

(*c*) Marshall Ward *dried* anthrax spores on glass *at* 70° *C.*, and found that they were subsequently rapidly destroyed by insolation.

In none of these three sets of experiments can the conditions be regarded as precluding the possibility of the formation of peroxide of hydrogen. Moisture must certainly have been present in Downes' and Blunt's experiments, and in smaller quantity in Marshall Ward's. In Momont's experiments the desiccation was doubtless the most complete, and at first sight the long insolation endured by his desiccated spores is very significant; but I do not regard it as wholly conclusive owing to the impossibility of comparing the deportment of spores of different origin, and also to the fact that Momont used the more delicate method of detecting their vitality—viz., subsequent cultivation in broth—whilst Marshall Ward used, I believe, agar or gelatin; and Downes and Blunt, Pasteur solution—culture media which are not as sensitive as broth.

There are other experiments, again, which bear upon the same subject. Thus Richardson has shown that the formation of peroxide of hydrogen

is due to the presence of some ingredient or ingredients in the urine, and that it is not formed by the insolation of water, or even of a solution of urea. If, then, the bacteria are suspended in water during insolation, there can be no generation of peroxide of hydrogen in the liquid. Now, as I have already pointed out in connection with my own experiments, a number of investigators are agreed that bacteria are much more resistant to insolation when suspended in water than when suspended in culture materials. It is, however, equally certain that they are actually destroyed, and sometimes even with great rapidity, when suspended in water. Now this at first sight would appear to demonstrate that the bactericidal effect of light, although accelerated by the generation of peroxide of hydrogen, may also take place without it. But we have already admitted the possibility of the generation of peroxide of hydrogen within the cells of imperfectly dried bacteria and their spores, so that it is surely still more easy to believe in the production of this material within the cells suspended in water to which air has access.

The evidence so far would appear to indicate, therefore, that, whilst the generation of peroxide of hydrogen is undoubtedly in many cases an active factor in the bactericidal influence of light, it is still uncertain whether it is indispensable for the process.

The question obviously raises another and far more general question which has long been before the chemical world—viz., as to how far oxidation can take place at all in the entire absence of water-vapour—and the evidence on this larger question goes entirely to show that all apparently direct low-temperature oxidations require the presence of water vapour. And, inasmuch as the bactericidal action of light is unquestionably a case of low-temperature oxidation there is the strongest presumptive evidence, as well as weighty experimental evidence, that water vapour, which practically means peroxide of hydrogen or some similar material, is essential for its manifestation.

One of the most important circumstances, from a practical point of view, connected with this bactericidal action of light is the greatly increased resistance which is exhibited by bacteria when suspended in water. On this subject I have for some time past been conducting some experiments, and although these are not yet by any means concluded, I may take this opportunity of referring to some of the results at which I have arrived. In the first place, I would point out how fallacious must be any comparison between the length of insolation withstood by even one and the same micro-organism in the hands of different observers, as so much depends upon their previous history and treatment. Thus I have found that the spores of anthrax produced at the ordinary room temperature (18–20° C.) are far more resistant than anthrax spores which have been obtained in an incubator at 35–38° C. It is necessary, therefore, in all such investigations, if comparisons are to be made, that the organisms should be taken from one and the same cultivation. In endeavouring to ascertain the greater susceptibility of bacteria to light when exposed in culture media I am proceeding by way of synthesis, making various additions to distilled water, and then determining how such additions affect the influence of insolation. In this manner I have already made some preliminary experiments with common salt and sodium sulphate.

The results of one series of these experiments are recorded in the following table:—

Action of Sunshine on Anthrax Spores suspended in Water.
(PERCY FRANKLAND.)

	Spores produced at 18–20° C.				Spores produced at 38° C.			
	3 hours' Sunshine 240		Darkness 490		3 hours' Sunshine 4		Darkness 476	
	NaCl	Na_2SO_4	NaCl	Na_2SO_4	NaCl	Na_2SO_4	NaCl	Na_2SO_4
1 % .	117	239	450	474	0	0	314	390
3 % .	81	218	384	426	1·5	1	132	343
10 % .	46	187	150	622	0	0	115	220

The figures refer to the number of anthrax spores contained in a cubic centimetre of water.

These results clearly show that the bactericidal action of light is very considerably greater in water containing common salt (1, 3, or 10 per cent.) than in distilled water; whilst, on the other hand, the addition of sodium sulphate in the same proportions has little or no influence in this respect. It is worthy of note also that an addition of 10 per cent. sodium chloride appears to exercise even a considerable bactericidal effect in the dark.

The specific effect of the sodium chloride in enhancing the bactericidal action of light is even still more conspicuously brought out by the series of experiments—also on anthrax spores—recorded in the following table:—

Action of Sunshine on Anthrax Spores suspended in Water.
(PERCY FRANKLAND.)

Spores produced at 18–20° C.

	Sunshine				Darkness			
	No additions	1% NaCl	3% NaCl	10% NaCl	No additions	1% NaCl	3% NaCl	10% NaCl
4 Hours .	16,000	14,000	8,000	5,000	13,000	13,000	9,000	12,000
11 Hours .	12,000	8,000	3,000	485	15,000	13,000	16,000	14,000
21 Hours .	378	39	49	0	18,000	15,000	14,000	9,000

The figures refer to the number of anthrax spores found in a cubic centimetre of water.

In addition to those departments of bacteriology which I have briefly touched upon in this survey, there are many others, also of great interest to chemists, which might have been appropriately introduced had time permitted. Thus the more important subjects which I have had to pass over are—

1. The discoveries in the bacteriology of agriculture, including such important chemical changes as nitrification and the fixation of free nitrogen by leguminous plants (which must be regarded as some of the most important contributions to vegetable physiology ever made) have shown that really the most important fermentation industry, and which is far more extensive than all other industries put together, is agriculture.

2. The production of ptomaïnes and poisonous albuminoids.

3. The phenomena of natural and artificial immunity, including the much-vexed questions of phagocytosis and the bactericidal properties of blood-serum and animal fluids.

In all these branches of bacteriology there is not only much that is of interest to chemists, but there is urgent need in the interests of science that these subjects should receive the attention of chemists, for almost in every direction in which bacteriology is advancing it is abutting on problems which will require the most profound knowledge of chemistry for their elucidation. In many respects, moreover, chemists are at a great advantage in the investigation of bacteriological problems, inasmuch as their thorough experimental training and manipulative skill afford the very best preparation for the study of this subject, in which the inductive method and a due appreciation of all the complicating factors which surround an experimental inquiry are in continual requisition. It must not, however, be supposed that a chemist can apply any bacteriological method with the same readiness that he can carry out some new chemical preparation from a published description. In the management of living bacteria there are a number of points which have to be carefully borne in mind which do not enter into one's consideration in dealing with inanimate matter. But this step from the inanimate to the animate is not more difficult for the chemist than for the vegetable or animal morphologist; indeed, it is perhaps not as difficult, for, whilst the morphologist is occupied only with statical considerations, in modern Chemistry our attention is turned more and more to dynamical problems.

In view of the vast fields of fruitful research which lie in this province of Biological Chemistry, it appears to me that the curriculum of chemical training should be more and more framed with a view to their successful exploitation. It is desirable that chemical students should take zoology, botany, and physiology as subsidiary subjects more frequently than they do at present in order that the barrier which is often felt to exist between Chemistry and Biology may be broken down and abolished.

The Circulation of Underground Waters.—Nineteenth Report of the Committee, consisting of Professor E. HULL (*Chairman*), Rev. Dr. H. W. CROSSKEY, Sir D. GALTON, J. GLAISHER, PERCY KENDALL, Professor G. A. LEBOUR, E. B. MARTEN, G. H. MORTON, W. PENGELLY, Professor J. PRESTWICH, I. ROBERTS, THOS. S. STOOKE, G. J. SYMONS, W. TOPLEY, C. TYLDEN-WRIGHT, E. WETHERED, W. WHITAKER, *and* C. E. DE RANCE (*Secretary*). (*Drawn up by* C. E. DE RANCE.)

THE inception of this committee was due to Professor Hull, who was appointed Chairman at Belfast in 1874, with your reporter as Secretary, for the purpose of investigating the circulation of underground waters in the permeable formations of England and Wales, and the quantity and character of the waters supplied to various towns and districts from these formations. It was felt last year that the labours of the Committee were nearly completed, and that they could not terminate their labours at a

more appropriate place of meeting than Nottingham, supplied as it is by a magnificent volume of underground water of absolute purity, and it is of interest to note that the Chairman of the Committee, Professor Hull, was consulted when these works were first initiated by the late Mr. M. D. Tarbotton, C.E.

It was last year resolved by the General Committee that your reporter 'be requested to draw up a final report embodying the whole of the facts obtained in counties,' and 'that it is advisable that the report in question should be issued as a separate publication.'

In compliance with this resolution your reporter has commenced the work of combining and systematising the previous eighteen reports, but he regrets that through pressure of official and other duties it has been impossible for him to complete the same, but he trusts to do so before the meeting at Oxford in 1894, when your committee will complete the twentieth year of their existence. The counties will be divided into five groups, and the report into as many separate sections, which your Committee recommend be sold separately.

Your reporter would in any case have ventured to suggest the continuance of the Committee for another year, in consequence of the exceptional season experienced, which has rendered it highly important to endeavour to trace the effect of the drought on underground water supply, and to institute a special inquiry as to the downward movement of the underground water line throughout the porous rocks of the country, and also as the rate of replacement of water by subsequent rains.

From observations made by Mr. E. J. Lowe, F.R.S., at Shirenewton Hall, Worcestershire, it appears that the entire rainfall of March and April was only 0·6 in., that from March to August 17 only 9·7 in., that 48 rainy days occurred, and 122 days without any rain: this, combined with an almost continuous high temperature, caused excessive evaporation of such rainfall as took place, the shade temperature being above eighty degrees seven days in April, one in May, six in June, five in July, and eight in August up to the 17th. Before the thunderstorm of June 15, on which 1·01 inch fell, the ground was dry to a depth of fifteen inches, but the rain only penetrated two inches from the surface.

The drought has made clearly apparent the weakness of gravitation supplies, the *quality* of the water in the best reservoirs steadily deteriorating as the *quantity* stored is reduced. The great value of underground supplies is as strongly brought out by the present yield of the Gainsborough Local Board well. It was sunk by Messrs. Timmins, Runcorn, at the recommendation of your reporter. The boring is now 1,351 feet in depth, and gives, in spite of the drought, the magnificent yield of 20,000 gallons per hour. The boring is artesian, the water rising from beneath 725 feet of Keuper Marls, being derived from the New Red Sandstone several miles distant.

Your Committee seek re-election, and reserve details received this year for incorporation in their final report next year. The Committee regret to have to note the death of their able Leicestershire member, Mr. James Plant, F.G.S., whose work has been of great value to the Committee and to the inquiry generally.

The Fossil Phyllopoda of the Palæozoic Rocks.—Tenth Report of the Committee, consisting of Professor T. WILTSHIRE (*Chairman*), Dr. H. WOODWARD, *and* Professor T. RUPERT JONES (*Secretary*). (*Drawn up by* Professor T. RUPERT JONES.)

[PLATE I.]

CONTENTS.

I. The *Phyllocarida*, from North Wales, referred to in the last report (for 1892, p. 299) as having been lent by Mr. G. J. Williams, F.G.S., of Blaenau-Ffestiniog, have been duly examined, and several described and figured, together with some other specimens, in the 'Geological Magazine' for May, 1893, pp. 198–203, plate 10, by T. R. Jones and H. Woodward. These comprise *Peltocaris Salteriana*, sp. nov. (fig. 1), *Dipterocaris Etheridgei*, J. and W., 1884 (fig. 3), *Aptychopsis Williamsii*, sp. nov. (fig. 7), *Ceratiocaris insperata*, Salter, 1866 (figs. 8 and 9); besides a fragment? (fig. 6), an undetermined specimen (cut, p. 203), a *Conularia* (fig. 2), and two Mytiloid shells (figs. 4 and 5).

The other specimens were:—

Hymenocaris vermicauda (Salter). Four pieces from the Middle Lingula-flags at Borth, and (Middle?) in the cutting near Wern; and (not rare) from the Upper-Tremadoc beds at Garth Hill; all near Portmadoc.

Saccocaris major (Salter). Small individual from the Upper Tremadoc at Tuhwnt i'r Bwlch.

Lingulocaris siliquiformis (Jones). From the Upper Tremadoc, at Garth Hill.

II. Several *Estheriæ*, from the Permian strata of Germany, submitted for examination by Baron Albert von Reinach, of Frankfort-on-the-Main, prove to be—

1. *Estheria striata* (Münster), var. *Muensteriana*, nov., Plate I., figs. 1, 2.

Length, 3·66 mm.; hinge-line, 2·46 mm.; height, 2·0 mm.

Near to the var. *Beinertiana*, Jones ('Monograph Fossil Estheriæ,' Palæont. Soc., 1862, p. 25, pl. 1, figs. 11–14), but more angular and sloping posteriorly, and not nearly so truncate on that border as in var. *Binneyana*, Jones, *loc. cit.*, fig. 9; nor rounded, as in var. *Tateana*, Jones, *loc. cit.*, figs. 15 and 18.

Like the before-mentioned varietal forms of *Estheria striata*, this has a straighter back than shown in the figures given by Goldfuss and De Koninck, and a sharper postero-dorsal angle than seen in any of the published figures. We may mention that fig. 8, pl. 1, 'Monogr. Foss. Esther.,' is less

oblong than the original figures referred to above, and is deeper (higher) posteriorly; fig. 9 is more truly oblong; figs. 11 and 13 are more oblique, sloping posteriorly; fig. 15 is oblique, but shorter than figs. 11 and 13; and fig. 18 is shorter and subquadrate.

The indications of interstitial ornament are feebly evident in some of those mentioned above, and we cannot find any in these now under examination.

Differing from the foregoing varieties it should be regarded, we think, as another variety, which we wish to specialise as *Estheria striata*, var. *Muensteriana*, thus naming it after Count Münster, who was one of the earliest observers of these Palæozoic Phyllopods and of other fossil bivalve Entomostraca.

In its postero-dorsal angle and long hinge-line this form much resembles the recent *Estheria Rubidgei*, Baird ('Proceed. Zool. Soc.,' 1862, pl. 15, fig. 3).

Fig. 1 illustrates the two valves lying together on the matrix, and in fig. 2 the left valve is seen without any perspective.

It is in bluish-grey Lebach shale of the lower part of the Rothliegende (Permian), at Altenstadt in the Wetterau, Grand Duchy Hessen, where it was discovered by Baron A. von Reinach with other fossils, namely, *Xenacanthus Decheni*, Goldfuss; *Acanthodes*, sp.; *Branchiosaurus amblyostomus*, Credner (*Protriton petrolei*, Gaudry), and some of the leading plants of the Permian series.

In these Lower Lebach shales from Altenstadt, Wetterau, A. von Reinach also found numerous small Ostracodes, which T. R. Jones and J. W. Kirkby have determined[1] as—

Leperditia Okeni (Münster), very common.
" " var. acuta, J. and K., } less common.
" " " oblonga, J. and K., }
" " " parallela, J. and K., rare.
" Youngiana, J. and K., rare.
Cythere superba ? J. and K., common.
Bairdia ? &c.

The series of formations yielding these Phyllopoda and Ostracoda have been especially studied of late years,[2] and belong to the Rothliegende of the Permian system of the Middle Rhine, Main, and Wetterau (equivalent to that of the Nahe and Saxony).

PART OF THE PERMIAN SYSTEM.

Upper Rothliegende	Kreuznach Beds. Wadern Beds.		
Lower Rothliegende	Upper, Middle, Lower } Lebach Beds	or	Sötern Beds. Tholey Beds. Lebach Beds.
	Upper, Lower } Cusel Beds		Upper, Lower } Cusel Beds.

Trans. Manchester Geol. Soc., vol. xxi. pt. 3, 1891, pp. 137–142, with plate.

[2] See Ch. E. Weiss, *Fossile Flora der jüngsten Steinkohlenformation und des Rothliegenden im Saar-Rhein-Gebiete*, 1869–72, p. 6; Kayser's *Lehrbuch der geologischen Formationskunde*, 1891, p. 149; and A. von Reinach, 'Das Rothliegende in der Wetterau und sein Anschluss an das Saar-Nahegebeit,' *Abhandl. Königl. Preuss. Geol. Landesanstalt.* Neue Folge. Heft 8, 1892, p. 3.

1.

× 15.

3.

× 15.

2.

× 15.

4.

× 20.

5.

× 20.

PALÆOZOIC ESTHERIÆ.

Illustrating the Report of the Committee on the Fossil Phyllopoda of the Palæozoic Rocks.

CARBONIFEROUS SYSTEM.

Upper, Middle, and Lower Ottweiler Beds.
Upper, Middle, and Lower Saarbrück Beds.

Estheriæ are also known in the Lower Lebach Beds at Baerweiler-on-the-Nahe.

2. *Estheria Reinachii*, sp. nov., Plate I., fig. 3.
Length, 3·2 mm.; hinge-line, 1·73 mm.; height, 1·86 mm.

This suboval *Estheria*, represented by two united valves (concave and one imperfect), is shorter and proportionally higher than fig. 2, and has a much shorter hinge-line, which is straight, and not quite equal in length to the height of the valve. The umbo is not so near to the antero-dorsal angle as it is in figs. 1 and 2, and therefore the ridges or lines of growth are less obliquely concentric with the umbo; they are also wider apart.

This form is not so bluntly rounded at the ends as *E. tenella* ('Monogr. Foss. Esther.,' p. 31, pl. 1, fig. 26; pl. 2, fig. 39; and pl. 5, figs. 1–7); and it is much too angular and sloping posteriorly to match Goldenberg's pl. 2, fig. 9. In this last-mentioned feature it shows an alliance with *Estheria striata*; but its shape and proportions decidedly separate it as a species, and we give it the name *E. Reinachii*, after Albert von Reinach, who discovered it in the light-grey shale of the Upper Lebach Beds in the Engelthal, near Altenstadt, in the Wetterau.

3. *Estheria Geinitzii*, sp. nov., Plate I., fig. 4.
Length, 1·4 mm.; hinge-line, 1·0 mm.; height, 1·05 mm.

This (left valve) is subquadrate, with the anterior and ventral more fully rounded than the posterior border. The back is straight, and the umbo is at its front end.

This somewhat approaches to the shorter and deep (high) forms of *Estheria minuta* ('Monogr. Foss. Esther.,' pl. 2, figs. 1, 5), but is readily distinguishable. It is still nearer in shape to a form of *E. Mangaliensis*, *op. cit.*, pl. 2, figs. 20, 23, but the latter has not the postero-dorsal angle sufficiently pronounced. *E. subquadrata* ('Geol. Mag.,' 1890, pl. 12, fig. 2) has some resemblance to the form shown by fig. 4, but it is not truncate anteriorly, and its postero-dorsal angle is weak.

The steep slope of the front edge, the full ventral curve, the contracted posterior moiety, and the well-pronounced postero-dorsal angle distinguish this form from any yet published. We dedicate it to our old friend Hofrath H. B. Geinitz, of Dresden, who has always been deeply interested in fossil Entomostraca and in the strata from which those of the Wetterau have been obtained.

This short form, deep (high) in its anterior moiety, is abundant (gregarious) in a dark greenish-grey, nearly black shale, ferruginous on one face, of the Lebach Beds, from the Boos Tunnel, on the Rhine-Nahe Railway, and on the same geological horizon as at Altenstadt.

4. *Estheria Geinitzii*, var. *Grebeana*, nov., Plate I., fig. 5.
Length, 1·2 mm.; hinge-line, 1·05 mm.; height, 0·9 mm.

Fig. 5 (right valve) is subtriangular and differs from fig. 4, owing to the great proportional length of the hinge-line and the less fully rounded

free margins. The front border is truncate, sloping downwards and inwards; and the hinder margin slopes downwards at once and forwards, and not partly outwards as in fig. 4.

These differences in outline do not seem to be due to bad preservation, for the ridges are truly concentric with the margins, as far as they are exposed; but they are varietal, if not sexual. Hence fig. 5 may be distinguished as var. *Grebeana*, after Herr Grebe, of the Prussian Geological Service, who found it crowded together with *E. Geinitzii* in the hard, dark-coloured Lebach shale from the railway tunnel near Boos, a village about a kilometre from Münster-on-the-Nahe.

III. In Katzer's 'Geologie von Böhmen,' III. Abtheilung, 1892, the following fossil Phyllopoda are mentioned :—

P. 1169, *Estheria cyanea*, Fr., from Lubna? (Lubno).
P. 1156 „ *tenella* (Jordan), from Nürschan (Nýřany), } Post-Carboniferous.
P. 1156 „ sp., from Třemošnà,

Since that date our friend Dr. Anton Fritsch has shown us some figures of Phyllopods which probably comprise those referred to above. These figures are, 1, an *Estheria*, from the lowest horizon of the Permian system of Bohemia, in the bituminous shale of Nyràn, near Pilsen; 2, *E. cyanea*, sp. nov., Fritsch, from the Middle Permian, in bituminous shale from Kaunovà; 3, an *Estheria*, from Upper Permian bituminous shale at Kàstialov; 4, an *Estheria* from the limestone with *Palæonicus Vratislavensis* of the Uppermost Permian at Braunau; 5, an *Estheria*, also from the Uppermost Permian Limestone. These, with some Ostracodes, will be published in due course by Dr. A. Fritsch in his 'Fauna der Gaskohle,' some parts of which have been already issued.

IV. S. S. Gorby, State Geologist, has issued some 'Advance Sheets from the Eighteenth Report of the Geological Survey of Indiana,' 8vo, Indianapolis, September, 1892, in which the Palæontology is done by S. A. Miller and S. A. Casseday (see p. 23). Some *Phyllocaridæ* of the family of *Pinacaridæ* are treated of, and at p. 77, pl. 9, fig. 37, the post-abdomen (trifid) of *Mesothyra Gurleyi*, n. sp., from the Kinderhook group, at Le Grand, Iowa, is described and illustrated; and at p. 78, pl. 9, figs. 43–46, *Macrocaris Gorbyi*, n. gen. et sp., from the Keokuk group, at West Point, Indiana. Of this latter form fig. 43 shows the interior of the carapace-valves and four abdominal segments. Fig. 44 gives four and part of another abdominal segment, and the post-abdomen slightly broken at the end. Fig. 45 is eight abdominal segments and the post-abdomen. Fig. 46 is a tooth, found in the same rocks, that may possibly belong to the internal masticatory apparatus.

V. In the 'Canadian Record of Science,' vol. v. No. 4, October, 1892, pp. 205–208, Mr. J. F. Whiteaves gives a 'Description of a new Genus and Species of Phyllocarid Crustacea from the Middle Cambrian of Mount Stephen.' The fossil is shown by a figure at p. 206, and named *Anomalocaris Canadensis*, gen. et sp. nov. The diagram and description do not make it appear to us to be a Phyllocarid.

VI. Mr. Robert Etheridge, jun., in the 'Records of the Geological Survey of New South Wales,' vol. iii. part 1, 1892, pp. 5–8, pl. 4, describes and figures four specimens of the *Hymenocaris Salteri*, M'Coy, and states his belief that they belong to *Lingulocaris*; and, as there is a *L. Salteriana*, he thinks that they should be called *L. Maccoyii*.

One or more specimens of this Australian species had been seen by Mr. J. W. Salter, and referred by him to *Caryocaris* with some doubt. We have adopted Mr. Salter's conclusion, both in a former report (for 1883) and in the 'Monogr. Brit. Palæoz. Phyll.,' Pal. Soc., 1892, p. 93. Comparing Mr. Etheridge's figures with those given of *Caryocaris* by ourselves (*op. cit.*, pl. 14, figs. 11–15), we find that one of ours is as large as any of the former, and that the modified shape of the ends of the valves does not necessarily remove them from *Caryocaris.*

VII. With respect to *Aptychopsis cordiformis,* sp. nov., and *Peltocaris anatina,* Salter, mentioned at page 299 of the report for 1892, Mr. J. E. Marr informs us that the words 'Coll. Marr' should not have been attached to the former in our 'Monogr. Pal. Phyll.,' part 2, 1892, p. 103, pl. 15, fig. 2, for it was collected long ago, being the only Palæozoic shield-shaped Phyllopod in the Cambridge Museum when Salter labelled it *Peltocaris anatina,* overlooking its real generic character, and perhaps regarding it as a distorted specimen. By this name the specimen has been referred to in lists of fossils as from the 'Wenlock,' and the real *Peltocaris,* which we have named *P. anatina* ('Monogr. Pal. Phyll.,' p. 114, pl. 16, figs. 4–9), is a 'Llandovery' fossil. It seems to be expedient to give the old name *anatina,* instead of *cordiformis,* to the *Aptychopsis* (p. 103), as intimated by Mr. Marr in the 'Geol. Mag.' for December, 1892, p. 535; and to distinguish the *Peltocaris* (p. 114), some specimens of which were collected by Mr. Marr, as *P. Marrii.*

VIII. We here append a table showing the Geological Distribution of the several Peltate Phyllopods described and figured in our Monograph and referred to at page 298 of the report for 1892.

Aptychopsis prima, Barrande „ „ var. longa, J. and W. „ „ var. secunda, J. and W.	Étage E e 1, Bohemia.
„ Barrandeana, J. and W.	Birkhill group (upper part of the Moffat series).
„ „ var. brevior, J. and W.	Birkhill group ?
„ anatina (Salter).	Lower Wenlock, Ulverston.
„ lata, J. and W.	Gala series.
„ glabra, H. Woodward.	Gala series.
„ Wilsoni, H. Woodward.	Riccarton series.
„ Lapworthi, H. Woodward	Gala series. Birkhill group. Skelgill Shales, Lake district.
„ ovata, J. and W.	Gala series.
„ Salteri, H. Woodward.	Wenlock Shale, South Wales.
„ subquadrata, J. and W.	Upper Silurian, Ireland.
„ angulata, Baily	Upper Silurian, Ireland. Brathay Flags (?), Lake district. Birkhill group ?
„ oblata, J. and W.	Riccarton series. Gala series. Birkhill group.
Peltocaris aptychoides, Salter	Gala series. Birkhill group.
„ Marrii, J. and W.	Birkhill group. Skelgill Shales.

Peltocaris patula, J. and W. { Birkhill group. / Skelgill Shales.
„ Carruthersii, J. and W. Birkhill group.
Pinnocaris Lapworthi, Eth. { Upper Silurian, Kendal. / Lower Silurian, Girvan.
Discinocaris Browniana, H. Woodward { Birkhill group. / Skelgill Shales.
„ ovalis, J. and W. Birkhill group.
„ undulata, J. and W. Birkhill group.
„ gigas, H. Woodward { Birkhill group. / Skelgill Shales.
„ Dusliana, Novák. Étage E e 1, Bohemia.

The general order of the strata is—

4. Pentland or Riccarton Series. Brathay Flags. (Wenlock Beds.)
3. Gala Series.
2. Moffat Series { 3. Birkhill group. Skelgill Shales. (Llandovery Beds.) / 2. Hartfell group. / 1. Glenkiln group.
1. Arenig Series.

The Eurypterid-bearing Deposits of the Pentland Hills.—Report of the Committee, consisting of Dr. R. H. TRAQUAIR (*Chairman*), Professor T. RUPERT JONES, *and* Mr. MALCOLM LAURIE (*Secretary*). (*Drawn up by* Mr. M. LAURIE.)

IN pursuance of the object for which the Committee were appointed Mr. Laurie spent three weeks in the Pentland Hills superintending the excavations necessary to expose the fossiliferous beds. Three men were employed on this work, and the grant was more than expended on wages alone. Considerable difficulty was experienced in clearing the beds owing to the constant falling in of the superincumbent rocks, which are much shattered. The fossiliferous beds were removed in as large masses as their highly-jointed condition would allow; and it seemed best to convey the material to some place where it could be examined at leisure. Part of the material (about one and a half ton) lies at present at Mr. Laurie's home in Duddingston, and the rest is safely deposited at Carlops, not far from the spot where it was procured.

Owing to considerable delay and difficulty in obtaining permission from the proprietor to make the excavations in question, Mr. Laurie has not had time to examine more than a very small quantity of the material procured.

The results, so far as they go, are promising, some half-dozen good specimens—including a large *Eurypterus* ? sp., *Stylonurus ornatus*, *Drepanopterus Pentlandius*, &c.—having been found, together with a large number of fragments of various forms.

Your Committee desire to be reappointed, and request that a further sum of 10*l.* be granted to provide assistance in developing the material which has been procured from the excavations.

The Volcanic Phenomena of Vesuvius and its Neighbourhood.—Report of the Committee, consisting of Mr. H. BAUERMAN, Mr. F. W. RUDLER, Mr. J. J. H. TEALL, *and* Professor H. J. JOHNSTON-LAVIS. (*Drawn up by* Professor H. J. JOHNSTON-LAVIS.)

Vesuvius.—During the first week of June 1892 much dust-bearing vapour escaped from the crater, but on the seventh of the month incandescent lava-cakes were being ejected, and a greater flow of lava was visible in the Atrio del Cavallo. The central crater increased in activity during the 8th and 9th, but on the 10th much dusty smoke issued during the day, but at night no reflection was visible. The following day less vapour was emitted, which only occasionally was darkened by dust. During the 12th, 13th, 14th, and 15th very little vapour was visible about the crater; a little more, sometimes white and sometimes dark from dust, issued from the last date till the evening of the 22nd, when a fresh gush of lava came forth in the Atrio del Cavallo, and a few incandescent cakes were ejected from the crater. On the 23rd more lava and high jets of incandescent lava-cakes were thrown out from the crater. The volcano was much quieter the next day, followed by marked repose during the rest of the month.[1]

During the next two months little of note occurred. The lava sometimes increased, and at other times it diminished, but it practically never stopped flowing. The central crater also varied within narrow limits, the vapour being occasionally charged with dust when a bit of crater edge collapsed and partly choked the main vent.

During September much the same state persisted. No reflection was ever visible from the central crater, though the usual column of vapour escaped freely, and was accompanied from time to time by dust and sand.

The month of October was a most unfavourable one, as for more than half of the month the cone was enveloped in cloud; but neither during this month nor during November and December did any marked change occur at the central crater. Occasionally a faint but uncertain glimmer was visible on some evenings over the main vent. Lava, as usual, continued to pour forth, flowing first to one side and then to the other of the Atrio, so that the point of its exit described in the former report has been raised, and a hill sloping away to the W., N., and E. continues to rise and to obliterate part of the space between the great cone of Vesuvius and the escarpment of Monte Somma.

During November the highest point of this boss, in the Atrio del Cavallo, piled up as it had been by the constant guttering forth of lava, was crusted over and surmounted by some ruined spiracles formed in June of the same year (1892). At certain points of this crust most beautiful sublimations of aphthitalite were deposited at a low red heat. In removing these deposits they were found to be of a dull red incandescence, but digging a few centimetres deeper amongst the scoriæ, of a bright red

[1] For much of the daily record I am indebted to Signor Avv. Bartolo Longo, proprietor of the observatory of the Valle di Pompei, and to Signors C. M. Tosti and Professor V. Capaccio, the observers. Unfortunately the record is not continuous, but what I have been able to obtain has been carefully checked and much extended by my closer observations on the volcano.

heat; a little hæmatite was visible, and that quite close to the aphthitalite near the cooling surface.

The aphthitalite occurred in thin plate-like crystals, very much resembling those of specular iron. They were simple hexagonal plates or compound feathers; only in the smaller crystals were the rhombohedral faces developed along the edges of the plate. Some were white with a faint opalescent tinge, but that variety was rare. Others were more opalescent and some quite milky. These latter shaded into examples of the most beautiful cerulean blue, and thence through varying tints of bird's-egg green to light chrome green and greenish yellow. The blue was due to copper impurities, and the green to iron and copper sulphates combined. The crystallisation was best developed in the whiter or more translucent specimens. Crystals of different tints were often blotched with a reddish coppery lustre, due to the contemporaneous deposition of fine transparent laminæ of hæmatite.

In some fissures of the hot lava were moss-like deposits of the mineral euchlorine (called by Scacchi *euclorina*), of bright emerald green colour. The deposit of this, however, was very limited. Several rifts in the new lavas have been most beautifully coated with very delicate feathery deposits of mixed sodium and potassium chlorides. Some had grown to such dimensions and solidity that they could be removed. This form of sublimate, although one of the commonest, is extremely rare in collections, for it is so fine and light that the slightest current of air reduces it to a fine powder.

At other spots thick saline crusts were deposited, but these proved to be very composite in nature, consisting of mixed sulphates and chlorides of the alkalies and alkaline earths, with much iron and a little copper.

If we carefully examine the history of eruptions at Vesuvius in which a record of the time and place of sublimates is made, and if we make constant observations of the vapour components, one fact becomes evident. The vapour that first escapes from boiling lava when it reaches the surface of the earth consists in great part of sulphurous acid and probably alkaline sulphites. Later, and more slowly, the hydrochloric acid and chlorides volatilise. Thus, when much new lava is issuing sulphurous acid is very obvious at the central crater, and around this incrustations of sulphur and sulphites prevail over chlorides, which are only deposited or produced by the escape of hydrochloric acid gas at more distant fumaroles. At the point of exit of the lava sulphites are deposited, but after the lava has flowed some distance chlorides are more abundant.

In May of this year when visiting the Atrio at the point of exit of the lava a phenomenon, of which I have never seen or heard of the like, could be studied. One of the curious conical spiracles, similar to those I described in the report of this committee for 1891, was puffing away with violent intermittent but not rhythmic blasts, and with the occasional escape of small fragments of lava. Watching this action, the cause of which has always appeared to me obscure, I noticed a large ball of incandescent pasty lava appear at the mouth of the spiracle at intervals, and as soon as the high pressure vapour found exit by its side it again fell back, and for a moment or two almost completely stopped any vapour escaping. It seemed to have nearly blocked the lower opening from which at times it was blown up by the vapour when the pressure increased. In fact it was somewhat like a ball valve. After watching this

lively display for nearly an hour we were at last rewarded by the spiracle clearing its throat of this obstruction, and its puffing became much more regular, softer, and more constant. I secured this expectorated ball which the spiracle had been so long in ejecting, and after allowing an hour for it to cool brought it home as an addition to my collection. I found round this spiracle several other such balls some 15 to 20 cm. in diameter, showing that the process had been repeated several times. The balls might be well taken for the so-called bombs, and is an explanation of a new though unimportant source of some of the structures included under the indefinite term of volcanic bomb.

It is deeply to be regretted that the numbering of the dykes in the Atrio del Cavallo, which cost so much labour and even money, is rapidly disappearing.

Campi Phlegraei.—The tunnel for the upper sewer in Naples has traversed the trachyte and entered a series of tuffs; but I propose to treat of these, as well as the peculiar piperno-like deposit of the Corroglio sewer, in another report or elsewhere, as the work is not yet quite complete. Here the peculiar piperno-like deposit has been traversed and a yellow tuff reached.

Few facts of importance, either of a local or general vulcanological interest, have during the year come to light; but while in Naples I continue to keep a sharp look-out, and record any facts of interest.

The reporter has to state that most of his available time during last winter was occupied in working out the eozoonal-like structures of the altered limestones of Monte Somma, a memoir on which subject has been presented to the Royal Dublin Society by Dr. J. W. Gregory and himself, in which they hope to have proved that these structures are all the result of metamorphism.

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest in the United Kingdom.—Fourth Report of the Committee, consisting of Professor JAMES GEIKIE (*Chairman*), Professor T. G. BONNEY, Dr. TEMPEST ANDERSON, Dr. VALENTINE BALL, Mr. JAMES E. BEDFORD, Professor W. BOYD DAWKINS, Mr. JAMES W. DAVIS, Mr. EDMUND J. GARWOOD, Mr. WILLIAM GRAY, Mr. ROBERT KIDSTON, Mr. ARTHUR S. REID, Mr. R. H. TIDDEMAN, Mr. W. W. WATTS, Mr. HORACE B. WOODWARD, *and* Mr. OSMUND W. JEFFS (*Secretary*). (*Drawn up by the Secretary.*)

YOUR Committee have the honour to append to this their fourth report a list of geological photographs added to the collection during the past year. The number shows an increase as compared with the previous year, and probably indicates the average number now to be expected within a similar period, if the operations of the Committee be continued. For the greater part, the photographs included in the present list are recent, having been taken during 1892–93, while those inserted in previous lists included a number which were photographed some years ago. It may be concluded that, among photographs of older date, the most

important are already registered in the collection, and that future additions will consist chiefly of new photographs. The Committee will, of course, gladly receive copies of older views showing features of geological interest, whenever such can be obtained, as these are frequently valuable for purposes of comparison with more recent pictures.

The Committee are again pleased to report a higher scientific quality of the views sent in, showing that the object of the Committee in securing illustrations of natural features of geological importance is becoming better appreciated.

The number of photographs received and registered from the date of the last report (June 1892) to the end of July 1893 is 140, bringing the total contents of the collection to 840. The new additions illustrate localities in the following geographical areas:—

ENGLAND AND WALES:		
Cheshire	14	
Devonshire	18	
Dorsetshire	26	
Hampshire	3	
Hertfordshire	3	
Kent	12	
Lancashire	7	
Middlesex	3	
Montgomeryshire	1	
Nottingham	2	
Staffordshire	2	
Surrey	3	
Yorkshire	11	
	—	105
CHANNEL ISLANDS		3
ISLE OF MAN		1
SCOTLAND:		
Edinburgh	10	
Fife	6	
Haddington	1	
Moray	8	
Perth	6	
	—	31
Total		140

GENERAL SUMMARY.

England	523
North and South Wales	73
Channel Islands	3
Isle of Man	23
Scotland	83
Ireland	123
Microscopic Sections	12
Total	840

No contributions have been received from Ireland since the last report. A further series of views is, however, being prepared for the Committee by Miss M. K. Andrews, of Belfast, and by Mr. Wm. Gray, Belfast.

The completion of photographic records of the various counties will be a work of time. Local societies are now giving greater attention to the subject, and when these efforts are systematically conducted the result will doubtless be satisfactory. The Committee are indebted to the delegates of the corresponding societies for their aid in bringing the

matter so prominently before their members. It is hoped that by next year contributions from several localities not hitherto represented in the collection will be received as the result of the special efforts now being made with this object.

Your Committee held a meeting at Edinburgh on August 5, 1892, and discussed plans for the furtherance of the work. Among other matters it was decided to obtain an expression of opinion from members who are practical photographers as to the best form of camera for use in the field. In geological expeditions it is necessary to consider the weight of *impedimenta* when the distance traversed is long or arduous. Several members advocated a small $\frac{1}{4}$-plate camera or 'Kodak,' from the negatives of which enlargements can be made—a plan successfully adopted in several instances. Mr. J. Hopkinson finds this form of instrument less successful with Tertiary sections, and writes: 'They require monochromatic or orthochromatic plates.' The best photograph for the Committee's purpose is that which shows the details of rock-structure most clearly, irrespective of size of plate. The Committee will be glad to hear the further opinions of members as to suitable instruments for field photography.

Several applications have been received for the loan of photographs from the collection for the purpose of being exhibited at soirées and meetings of local societies. In view of the risk of loss and deterioration of photographs so transmitted and for other obvious reasons, the Committee, while appreciating the general interest shown in their scheme, regret their inability to sanction the loan of any part of the collection. In order, however, to meet the wishes of societies who may desire to show their members examples of the photographs collected by the Committee, it has been decided to form an album containing duplicates of selected views, which will be available for the use of societies who may apply for the same for purposes of exhibition. Donations of duplicate prints will be welcomed for this purpose. Applications for the loan of an album of duplicate views should be addressed to the Secretary. Up to the present, only some half-dozen duplicates have been received; but it is hoped that this number will be considerably augmented. It is proposed to include in the 'duplicate' series about fifty photographs. These will be useful in spreading information in various quarters as to the requirements of the Committee and the progress of their scheme for the collection of geological photographs, and will doubtless lead to an extended interest being taken in the subject.

It may be mentioned that the Secretary was enabled during last winter to deliver several lectures on the work of the Geological Photographs Committee in Liverpool, Chester, Manchester, Birkenhead, Rochdale (on the invitation of the Rochdale Literary and Scientific Society), and elsewhere. The lectures were illustrated by lantern slides taken from photographs in the collection and from other sources.

At the Edinburgh meeting a large selection from the collection was exhibited in a room placed at their disposal by the Committee of Section C. The series was augmented by special exhibits of enlargements by Dr. Tempest Anderson and Mr. W. Lamont Howie, to whom the Committee beg to tender their thanks. In this room were also exhibited a series of photographs taken under the superintendence of the Geological Survey of Scotland.

The number of photographs now brought together precludes the possibility of the whole being arranged for exhibition at every meeting of

the Association, but, so far as local arrangements permit, it is proposed to continue the exhibition of a selection of the views, including the photographs presented since the previous meeting.

The system of mounting, in order to preserve the photographs from injury (alluded to in the last report), has proved to be satisfactory; and the mounting and arrangement of the entire collection are now being proceeded with. The mounts adopted are of standard size, $15\frac{1}{2} \times 12$ inches, provided with perforated edges to facilitate proper arrangement. These will be supplied to donors of photographs who are willing to mount their own views.

Reference has been made in former reports to a proposed publication consisting of reproductions of selected typical geological photographs. Having fully considered the proposal, the Committee have come to the conclusion, having strict regard to the objects for which they were appointed, that this matter lies beyond their province; they will be glad, however, to afford assistance to any publisher or other person who wishes to undertake the suggested publication, so desirable from an educational point of view.

It is with much regret that the Committee have to record the decease of another of their members. In Mr. J. W. Davis, F.G.S., of Halifax, they had an esteemed colleague and an active member. The fine series of photographic illustrations issued by the Yorkshire Geological and Polytechnic Society was presented through Mr. Davis, whose influence was always exerted towards the furtherance of the work of the Committee.

Owing to the illness of the Secretary the completion of the task of arranging the mounted photographs in portfolios has had to be deferred.

The Committee request reappointment and renewal of the grant (which was not drawn this year) in order that further progress may be made with the collection, with a view to its being rendered as complete and as widely representative as possible.

Several photographs were received during the year without any particulars of locality or even of photographer. These could not be included in the following list. It will greatly aid the work of the Committee if photographs presented are accompanied by as many details as may be possible. When not mounted on the standard mounts, prints should be forwarded *flat* (not rolled). Copies of forms for the insertion of descriptive details, and of the circular of instructions (the purpose of which is to secure uniformity of action), will be supplied on application to any member of the Committee.

FOURTH LIST OF GEOLOGICAL PHOTOGRAPHS.

(TO JULY 1893.)

NOTE.—This list contains the subjects of geological photographs, copies of which have been received by the Secretary of the Committee since the publication of the last report. Photographers are asked to affix the registered numbers, as given below, to their negatives for convenience of future reference.

Copies of photographs desired can, in most instances, be obtained either from the photographer direct or from the officers of the local society under whose auspices the views were taken.

The price at which copies may be obtained depends upon the size of the print and local circumstances, over which the Committee have no control.

The Committee find it necessary to reiterate the fact that they do not assume the copyright of any photographs included in this list. Inquiries respecting them, and applications for permission to reproduce photographs, should *not* be addressed to the Committee, but to the photographer direct.

ENGLAND AND WALES.

CHESHIRE.

Photographed by E. TIMMINS, *C.E., Runcorn. Size* 6 × 4 *inches.*

Regd. No.		
701	Runcorn	Red marl and waterstones

Photographed by F. J. EATON, *Roseville, Maghull, Lancashire. Size* 6 × 4 *inches.* (*Per* OSMUND W. JEFFS.)

1–742	Storeton	Footprints of *Cheirotherium Storetoniense* (Morton) on slabs of Keuper sandstone (two specimens)
743	„	Footprints of *Rhynchosaurus* (Keuper)
744	„	„ „ with ripple-marks in Keuper
745–746	„	Footprints of *Rhynchosaurus* of various (?) Saurians (species undetermined)

Photographed by EDWARD WARD, 249 *Oxford Street, Manchester.* (*Per* OSMUND W. JEFFS.) *Size* ¼ *plate.*

805	Helsby Hill . . .	Keuper resting on Bunter
806	„ . . .	Fault at roadside, foot of hill
807–809	Norton	Fault with slickensides
815	Acton Grange	„ „
816	Pool Hall	Slickensided surface (and other views along the course of the Manchester Ship Canal)

DEVONSHIRE.

Per W. A. E. USSHER, *F.G.S.*, 5 *Hoe Park Terrace, Plymouth.* (*Series of views illustrating Granite Structures.*) *Size* 6 × 4 *inches. Photographer not stated.*

761	Dartmoor	'The Sphynx,' Tavistock
762	„	Vixen Tor „
763	„	Kestor, Chagford
764	„	Bowerman's Nose, Chagford
765	„	Hound Tor
766	„	Hey Tor, from the east
767	„	„ „ west

Photographed by Miss M. E. JOHNSON. *Size* 4 × 3 *inches.*

768	Salcombe, mouth of estuary	Contortion in 'green rock' series (altered diabase)
772	Tinsey Head, N. of Start Point	Devonian rocks

Photographed by A. R. Hunt. *Size* 4 × 3 *inches.*

Regd. No.		
769	Seacombe Sands . .	Platform of (so-called) 'Chloritic Series' with mica schist interstratified
770	" " . .	'Green rock' (altered diabase) with mica schist, affected by small faults

Photographed by Miss Alice Whidborne. *Size* 8 × 6 *inches.*

773	Thurlestone Beach . .	Sea-stack. ? Permian
774	Elbury Cove, Brixham .	Upper Devonian limestone; inverted fold in red shales

Photographed by Archibald Coke. *Size* 6 × 4 *inches.*

775	Westward Ho! The Pebble Ridge	Middle Culm Measures forming cliffs

Photographer not stated. Size 6 × 4 *inches.*

771	Sharp Tor, Bolt Head .	Rugged weathering of mica schist
776	Clovelly	Eggesford grit (Upper Culm Measures)
777	Ilfracombe	Inverted anticlinal of Ilfracombe slates (Middle Devonian)
778	Great and Little Hangman Hills, West Challicombe Bay	'Hangman grits,' overlain by Middle Devonian

Dorset.

Photographed by Captain Marshall Hall, *J.P., F.G.S., Easterton Lodge, Parkstone, R.S.O. Size* 6 × 4 *inches.*

749–750	Hanworthy (Railway Junction)	Bagshot sands, with beds of pottery clay and ironstone

Photographed by Godfrey Bingley, *Leeds.* (*Per* J. E. Bedford, *F.G.S., Leeds Geological Association.*) *Size* 6 × 4 *inches.*

779–781	Swanage, Tilby Whim .	Portland beds
818–819	Durlston Head . . .	" "
782–786	Stair Cove, Lulworth .	Contorted strata
822–823	Durlston Bay . . .	Cliff sections
790	Swanage, Studland Bay .	Chalk
791–792	Ballard Head . . .	"
793	'Old Harry' Bay . .	Isolated pillar of chalk
824	Lulworth Cove . . .	General view

Photographer not stated. Size ¼ *plate.*

825	West Bay, Bridport . .	Fault (Lias)
826	Bridport, North Allington .	Junction of Upper and Middle Lias

Hampshire.

Photographed by Godfrey Bingley, *Leeds.* (*Per* J. E. Bedford, *F.G.S., Leeds Geological Association.*) *Size* 6 × 4 *inches.*

787–789	Bournemouth, Shelly Chine	Bagshot beds

HERTFORDSHIRE.

Photographed by JOHN HOPKINSON, *F.G.S., The Grange, St. Albans. Size* 4 × 3 *inches.*

Regd. No.		
732	Radlett (roadside section between Radlett and Colney Street)	Upper Chalk, capped by Reading beds
733	St. Albans (railway cutting $1\frac{1}{2}$ mile north of station)	Boss of Upper Chalk, capped by Reading beds, Glacial gravels, &c.
734	St. Albans (gravel pit) .	Hertfordshire conglomerate and disturbed Reading beds

KENT.

Photographed by WM. GOODE, *Mulgrave Road, Sutton, Surrey. Size* 6 × 4 *inches.*

704	Tunbridge Wells . .	The 'Toad Rock'

Photographed by H. D. GOWER, 16 *Wandle Road, Croydon, Surrey. Size* 6 × 4 *inches.*

706	Tunbridge Wells . .	The 'Toad Rock'

Photographed by Captain McDAKIN, 15 *Esplanade, Dover. (Per East Kent and Dover Natural History Society.) Size* 8 × 6 *inches.*

707	Newington, Folkestone .	Landslip
708	„ „ .	'Combe' (or 'cwm') in chalk
709–710	Cornhill cliffs . . .	Chalk
795	St. Margaret's Bay, looking south	Upper Chalk
796	St. Margaret's Bay, looking north	„
797–798	West of Dover (railway cutting)	Indication of raised beach
799–800	Sandgate	Folding and fracture of wood; effect of landslip

LANCASHIRE.

Photographed by R. G. BROOK, *St. Helens. Size* 8 × 6 *inches.*

702	St. Helens	Section in Coal Measures
736	„ Quakers' Burial Ground	Large erratic boulder

Photographed by JOHN JACKSON, *South Dene, Rochdale. (Per* S. S. PLATT, *F.G.S., Borough Surveyor, Rochdale.) Size* 9 × 6 *inches.*

728	Cowm Top, Castleton, near Rochdale	Large boulder (andesite) removed to Public Park, Rochdale. Weight of boulder 7 tons

Photographed by EDWARD WARD, 249 *Oxford Street, Manchester. Size ¼ plate.*

Regd. No.		
810, 813–814	Warburton . .	Red marls; fault
817	Manchester . .	Large boulder, found in Oxford Road, *in situ*

MIDDLESEX.

Photographed by JOHN HOPKINSON, *F.G.S., The Grange, St. Albans. Size* 4×3 *inches.*

729	Harefield; North Chalk pit	Upper Chalk
730, 731	„ South Chalk pit	„ with glacial gravel and 'pipes'

MONTGOMERY.

Photographed by R. G. BROOK, *St. Helens. Size* 6×4 *inches.*

735	Tyn-y-wern	Denuded rock masses broken from the mountain and fallen down the vale

NOTTINGHAM.

Per J. SHIPMAN, *F.G.S., Nottingham. Size* 6×4 *inches. Photographer not stated.*

747	'Himlack Stone' . .	Triassic outlier
748	'Blidworth Pillar' . .	„ (conglomerate)

STAFFORDSHIRE.

Photographed by F. BONNEY, *F.R.G.S., Rugeley. (Per* Professor T. G. BONNEY, *F.R.S.) Size* 6×4 *inches.*

751	Hednesford (Rugeley and Cannock Railway)	Bunter Pebble Beds
752	Satnall Hills (gravel pit, between Rugeley and Stafford)	„ „

SURREY.

Photographed by WM. GOODE, *Mulgrave Road, Sutton. Size* 8×6 *inches.*

705	Godstone	Interior of pit, showing termination of workings
820	„	Pits in lower beds of Upper Greensand
821	Tilburstow Hill . .	Sand, with irregular beds of ironstone

YORKSHIRE.

Photographed by GODFREY BINGLEY, *Leeds. (Per* J. E. BEDFORD, *F.G.S., Leeds Geological Association.) Size* 8×6 *inches.*

794	Rowley's quarry, Meanwood Valley, Leeds	Fossil tree in Ganister beds, Lower Coal Measures

Photographed by W. Grantham. (*Per* J. W. Woodall, *F.G.S., St. Nicholas' House, Scarborough.*) *Size* 8 × 6 *inches.*

Regd. No.		
834,839	Langtoft, near Driffield .	Destructive effects of water on chalk hills
835,840	„ „ .	Cottage destroyed by flood caused by waterspout
833,836	„ „ .	Rift and detritus on chalk hills
837,838	„ „ .	Pond formed by waterspout
831	„ „ .	Rift probably caused by heavy rainfall in 1673; reopened by a similar fall in 1892
832	„ „ .	Talus of chalk detritus

CHANNEL ISLANDS.

Island of Jersey.

Photographed by Geo. A. Piquet, 68 *New St. John's Road, Jersey. Size* 8 × 6 *inches.*

738	St. Lawrence Valley . .	Schistose rocks
739	Grève-au-Lançon, St. Owens	Sea-cliff
740	Do. (nearer view) .	Sea-cliff and raised beach

ISLE OF MAN.

Photographed by G. Patterson, *Ramsey* (*per* P. M. C. Kermode, *F.G.S.*). *Size* 8 × 6 *inches.*

737	Maughold Head . .	Contorted slates

SCOTLAND.

Edinburgh.

Photographed by Wilbert Goodchild, 2 *Dalhousie Terrace, Edinburgh. Size* 6 × 4 *inches.*

712	Craig W. end of Blackford Hill	Alternations of lavas and tuffs
713	Arthur's Seat, south side .	Agglomerate piercing Carboniferous volcanic rocks
714	„ „ .	Roche moutonnée
715	„ Salisbury Craigs	Spheroidal weathering of dolerite
716	Glencorse	Conglomerate (Old Red) with intrusive mass of felsite
718	Blackford Hill, south side .	Rock surface undercut by glacial action
722	Salisbury Craigs . .	Shale in dolerite
724	Corby Craig . . .	Lava
726	Pentland Hills, from Buckstone	Lavas and tuffs
727	Glencorse, looking north .	Screes of felsite

Fifeshire.

Photographed by Wilbert Goodchild, 2 *Dalhousie Terrace, Edinburgh. Size* 6 × 4 *inches.*

711	Craigs, east of Burntisland	Lavas and tuffs
717	Kincraig, west of Elie .	Columnar basalt and tuffs
719	Kinghorn, east of . .	Ejected blocks of lava
720–721	Devil's Cave, west of Elie .	Tunnel eroded by sea
723	Burntisland and Kinghorn (between)	Weathered tuffs

Haddingtonshire.

Photographed by Wilbert Goodchild, 2 *Dalhousie Terrace, Edinburgh. Size* 6 × 4 *inches.*

Regd. No.		
725	Bass Rock, from the south	Trachyte

Morayshire.

Photographed by W. Lamont Howie, *Cornbrook House, Eccles. Size* 4 × 3 *inches.*

Series of eight views showing pillars of denudation, Old Red conglomerate, near Fochabers.

753	Valley of Alltdearg Burn .	Large pillar at entrance to valley
754	" " .	Large pillar at head of valley
755	" " .	General view
756	" " .	General view at confluence of Alltdearg with Spey
757	" " .	View of valley from above
758–759	" " .	View of valley showing earth-pillar
760	" " .	Earth-pillar looking down the river

Perth.

Photographed by Henry Coates, *F.R.S.E., Perthshire Society of Natural Science. Size* 8 × 6 *inches.*

801	Crieff and Comrie . .	Uptilted sandstone
802–803	Crieff	Boulders

Photographed by Wm. Ellison (*per* Henry Coates, *F.R.S.E., Perth*). *Size* 8 × 6 *inches.*

804	Craigie Burns Hill, Dunkeld	'The Rocking Stone'; mica-schist boulder

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The Registration of the Type Specimens of British Fossils.—Fourth Report of the Committee, consisting of Dr. Henry Woodward (*Chairman*), Rev. G. F. Whidborne, Mr. R. Kidston, Mr. J. E. Marr, *and* Mr. A. S. Woodward (*Secretary*).

The Committee have to report that the number of lists received is still insufficient to attempt the tabulation of results. During the present year the Manchester Museum has published a list of its type specimens of fossils, prepared by Mr. H. Bolton; and the Rev. P. B. Brodie has furnished a MS. list of the large number of types and figured specimens in his private collection. A short supplementary list has also been published by the Woodwardian Museum, Cambridge (H. Woods, 'Geol. Mag.,' Dec. 3, vol. x. 1893, pp. 111–118). Notwithstanding the slow progress, the Committee feel that their existence has an important influence in obtaining the registration of specimens which might be overlooked, and they desire to be reappointed.

The Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities.—Report of the Committee, consisting of Mr. J. HORNE (*Chairman*), Mr. DAVID ROBERTSON, Mr. T. F. JAMIESON, Mr. JAMES FRASER, Mr. P. F. KENDALL, *and* Mr. DUGALD BELL (*Secretary*). (*Drawn up by* Mr. HORNE, Mr. FRASER, *and* Mr. BELL; *with Special Reports on the Organic Remains, by* Mr. ROBERTSON.)

[PLATES II, III.]

CONTENTS.

I.—INTRODUCTION.

The investigation of the character of the high-level shell-bearing deposits at Clava, Chapelhall, and other localities has been undertaken with the view of re-examining the evidence bearing on the submergence of Scotland during the Glacial period. Recent contributions to the literature of glacial geology in this and other countries have raised doubts regarding the extent of this submergence. Selecting the shelly clay at Clava as a typical example of the Scottish high-level shell beds, the Committee have meanwhile confined their operations to this locality. The grant from the British Association having proved insufficient for the work, the investigations at Clava have been completed by a grant obtained through the courtesy of Sir Archibald Geikie from the Council of the Royal Society of London, and by private subscriptions raised by the Secretary of the Committee.

II.—GEOGRAPHICAL POSITION.

The shell-bearing deposit at Clava occurs on the east side of the valley of the Nairn, and six miles due east of the town of Inverness. Situated on the south bank of the Cassie Burn, a tributary of Allt Ruadh (the Red Burn), the latter being an affluent of the river Nairn, the shelly clay is about half a mile distant from the Nairn, about 200 feet above the level of that river at Clava, and about 500 feet above the sea-level (see map, p. 499).

III.—PREVIOUS OBSERVATIONS REGARDING THE SHELLY CLAY.

The first description of this deposit was given by Mr. James Fraser, C.E., Inverness,[1] who made a careful examination of the section

[1] See *Trans. Geol. Soc. Edinb.*, vol. iv. Part ii. 1882; also *Trans. Inverness Field Club*, vol. ii.

then brought to light, together with the superficial deposits in the surrounding district. The results obtained by him may thus be briefly summarised:—

(*a*) Section:

	Feet
1. Soil and gravel / 2. Boulder clay	50
3. Fine sand, stratified	20
4. Shelly clay, bottom not reached	$7\frac{1}{2}$

(*b*) Chemical analyses (1) of the shelly clay, (2) of the overlying sand, and (3) of the brown clay, 233 yards south-west of the 'main section,' by Mr. W. Ivison Macadam, Edinburgh, were given.

(*c*) A list of the organic remains (comprising several Arctic shells), determined by Mr. David Robertson and Mr. T. F. Jamieson, was published.

(*d*) From the character of the deposit and the condition of the organic remains, as described by the foregoing authorities, Mr. Fraser inferred that the shelly clay was *in situ*, and indicated a depression of the land to the extent of over 500 feet prior to the deposition of the overlying boulder clay.

In 1886 Dr. H. W. Crosskey made an examination of the shelly clay and glacial deposits in the Nairn Valley; his conclusions confirmed those previously published by Mr. Fraser.[1]

Recently several objections have been raised[2] against the acceptance of these conclusions, so that further investigation became desirable.

IV.—Detailed Examination of the Shelly Clay and Associated Deposits by the Committee.

The shelly clay is found at or under the base of a prominent broad-topped ridge of drift on the south bank of the Cassie Burn, which there flows along the foot of a bluff cliff of glacial deposits (see photo-engravings, Plates II. and III.). This conspicuous ridge is traceable for upwards of two miles in a north-easterly direction, parallel with the river Nairn, and for about 1,200 yards in a south-westerly direction. About 200 yards nearer the river, and nearly 100 feet lower, occurs a narrower ridge, along the top of which runs the Craggie and Cawdor road for more than a mile. These parallel ridges of drift are flanked on the south-east sides by marshy or alluvial hollows; indeed, at the point where the shelly clay occurs the Cassie Burn flows for some distance along the hollow separating the two ridges. Both ridges have an irregular fall of about 50 feet per mile towards the north-east; the upper ridge being nearly uniform, and the lower one irregular in its fall.

A.—*Excavation of 'Main Pit.'*

The Committee began their examination of the shelly clay by excavating a large pit or trench at the base of the cliff on the south bank of the Cassie Burn. The site of the pit was 430 yards distant from the junction of the Cassie Burn with Allt Ruadh. At the outset the length of the trench was 25 feet and the breadth 15 feet at the surface, but as

[1] *Trans. Inverness Field Club*, vol. iii.

[2] *Trans. Geol. Soc. Glasgow*, vol. ix.; *Brit. Assoc. Rep.*, 1892, p. 714.

the work proceeded it had to be made longer and wider, owing to slips of clay and sand from the face of the cliff. Though the work was seriously impeded by unfavourable weather, the excavation was eventually successful in showing an admirable section of the shelly clay and underlying gravel, without reaching the solid rock.

The section thus revealed by the exposed surface of the cliff and the trench was as follows:—

	Feet
1. Surface soil and boulder clay from top of ridge of drift =43 feet, of which only the lower 12 feet exposed to view (see Section of 'Main Pit,' p. 15)	12
2. Fine sand	20
3. Blue shelly clay	16
4. Coarse yellowish-brown gravel	10

Throughout this report this excavation is referred to as the 'main pit' or 'main section' of shelly clay.

A careful examination of these various deposits was made on the ground by most of the members of Committee, with the following results:—

1. *Boulder Clay, overlying the sand and shelly clay.*—As this deposit is extensively developed in the neighbourhood of Clava, the Committee selected a typical section for examination, where there is a splendid exposure of the included blocks. The section occurs on the south bank of the Cassie Burn, from 130 to 160 yards south-west of the 'main pit,' where the boulder clay also overlies the shelly clay, and where the deposit resembles in every particular that above the 'main pit.'

The deposit is of a light brown colour, and the matrix consists mainly of fine sand; the stones are more or less well-rounded, varying in size from fine gravel up to 2 feet in diameter. Many of the blocks of sandstone are finely striated along the longer axis. The deposit is more sandy and gravelly than the typical ground moraine or till of Scotland. But though the proportion of clay among the materials is small, it is usually sufficient to bind them into a compact mass.

The largest proportion of the included blocks has been derived from the adjacent Lower Old Red Sandstone strata. Of these many have been obtained from the micaceous flagstones occurring *in situ*, in the Easter Daltullich Burn, the river Nairn, and other localities to the west and south-west of Clava. On referring to the table of percentages of stones, which has been prepared to show the variation in the character of the included blocks in the shelly clay and associated deposits, it will be seen that while the percentage of Old Red Sandstone blocks in the overlying boulder clay varies from 56 to 76 per cent., in the shelly clay it amounts to only 17 per cent. No organic remains have been found in this deposit.

2. *Fine Sand.*—The sand underlying the boulder clay in the 'main pit' is of a yellowish brown colour and fine-grained. At first sight it seems to be free from stones, but on closer examination a few may be detected under a quarter of an inch in size. The lowest 4 feet of sand overlying the shelly clay is very compact, harder even than the latter deposit. The line of junction between the sand and shelly clay is nearly horizontal, and clearly defined by a difference in the colour and texture of the materials. The boundary line between the sand and overlying boulder clay is less distinct. After a heavy rainfall or the frosts of winter, lines

of stratification are visible. No organic remains have been found in this deposit.

3. *The Shelly Clay.*—The highest part of the shelly clay near the south-east end of the 'main pit' is $503\frac{1}{2}$ feet above sea-level. From the levels taken in 1882, when a small excavation was made by Mr. Fraser, the height of the shelly clay at the front of the west end of the present 'main pit' was 501 feet. The top of this deposit where visible rises slightly towards the east or south-east to the extent perhaps of 1 foot in 20 or 25 feet.

The shelly clay as exposed in the 'main pit' varied from 14 to 16 feet in thickness. It is a tenacious clay or silt of a blue dark grey colour, save the lowest 2 feet, where the tint is brownish grey. At this lower level there is an admixture of fine gravel. The boundary line between the shelly clay and underlying gravel is clearly defined. There is no intermingling of the two deposits.

There are slight traces of stratification in the blue clay. At a depth of $3\frac{1}{2}$ feet a horizontal line was observed in the deposit after exposure for several days to heavy rain, but scarcely any part of this line could be traced when a fresh surface was revealed. At a depth of $6\frac{1}{2}$ or 7 feet, horizontal streaks or thin layers of sand or fine gravel occur, but not in continuous layers.

It is also important to note, as throwing light on the origin of the deposit, that the silt was traversed at certain levels by annelid burrows, more or less vertical, the tracks being darker in colour than the surrounding silt. The burrows in most cases were laterally compressed.

Of special interest also is the occurrence of a series of nearly vertical cracks or fissures traversing the clay in a uniform direction, viz., north-west and south-east, the tops of the fissures being bent towards the north-east. An attempt was made to photograph these fissures or cracks, which formed a conspicuous feature in the deposit.

The upper 12 feet of blue clay is almost free from stones; those which do occur within these limits vary from the size of peas to $1\frac{1}{2}$ inch in diameter as a rule. But they become more numerous and slightly larger at a depth of about 6 feet. In this upper portion they are nearly all well-rounded and of the harder varieties. The lowest 3 or 4 feet of the deposit (especially the lowest 18 inches) contains a larger proportion of stones, varying in size from peas to 2 inches across, and almost all well-rounded.

At a lower depth than 6 feet a few stones of a larger size than the foregoing dimensions were found, the largest varying from 3 to 6 inches across, some being well-rounded and some subangular. The largest stone met with in the blue clay, measuring 9 inches by 7 inches by $4\frac{1}{2}$ inches, consists of dark micaceous gneiss: it is partially rounded, ice-grooved on one side, and with the mark where a *balanus* had been attached on one end of the grooving. Two small stones with several nearly entire *balani* were found at the very bottom of the shelly clay at the south-west end of the pit.

During a subsequent inspection of the 'main pit' two small striated stones of fine-grained sandstone were observed in the lowest 6 feet of the deposit; and about the same level, two rounded stones (4 inches by 3 inches) with fresh *balanus* marks.

Only three striated stones were met with in the shelly clay, the general well-rounded character of the stones and the absence of striations being a striking feature of the deposit.

A careful examination of the included blocks showed the following interesting results: 59 per cent. consist of micaceous gneiss, about 10 per cent. of granite, about 12 per cent. of quartz-schist and mica-schist, &c., or in all 81 per cent. of the older crystalline rocks, and only about 17 per cent. of Old Red Sandstone.

One small block of Jurassic grit was detected in the shelly clay which was sent to Mr. Horace Woodward, of the Geological Survey of England, now engaged in mapping the Secondary rocks in Scotland, who has kindly furnished the Chairman of the Committee with the following note on the specimen:—'There are gritty beds at the base of the Lias, in the Lower Oolites, and in the Middle Oolites of the Brora country that closely resemble your specimens. The nearest approach to it is in specimens of Lower Oolite from Skye and Raasay. This particular bed is part of the basement beds of the Inferior Oolite at the base of the so-called "Great Estuarine Series." Curiously enough, we get no exposure of these beds in the Sutherland region—only the upper parts of the Lower Oolite (with the Brora coal). Hence my opinion is that your specimen most nearly approaches in character to beds of Inferior Oolite (basement portion).'

Notwithstanding the strong resemblance of this block of Jurassic grit to strata in Skye and Raasay, the Committee are of opinion that it has been derived from some area of Secondary rocks in the North-east Highlands. The nearest point to Clava where Jurassic rocks occur *in situ* is about 12 miles due north of the shelly clay, on the shore of the Black Isle, at Ethie, near the Sutors of Cromarty. The occurrence of this solitary block of Jurassic grit is of considerable importance, as will be readily admitted when we summarise the evidence bearing on the direction of the ice-flow in the neighbourhood of Inverness (see map for relative positions of Clava and Ethie, p. 499).

Shells are found throughout the whole of the blue clay or at least from within 5 or 6 inches of the top to the bottom of the deposit. They are most abundant at a depth of 2 or 3 feet from the top. Many of the shells are quite whole at all depths, others are partially crushed, others are in a tender or decaying condition. In the lowest part of the clay the shells are of a darker colour, and many of them are so decayed that they will scarcely bear handling. At all depths fragments of *Mytilus* are rather numerous, but so decayed that a whole specimen cannot be obtained. The prevalent shell is *Littorina littorea.*

In the case of many of the shells the epidermis is in perfect preservation, and no indications of ice-markings or abrasion could be detected on any of them. The absence of ice-markings on the shells is a remarkable feature, which serves to distinguish the Clava shelly clay in one particular from the shelly boulder clay of Caithness and Orkney. In the latter many of the shells are striated like the stones in the deposit.

It is important to observe, however, that some of the bivalves, such as *Astarte*, with both valves attached, showing no signs of abrasion and otherwise complete, were found with both valves crushed together.

During the examination of the 'main pit' on October 15, 1892, the following observations were made regarding the position of some of the shells:—

Astarte, single valve	at 6 feet depth,	concave side up.
Natica,	,, ,,	mouth up.
Littorina (large),	,, ,,	mouth down.
Natica,	,, ,,	mouth down.
Natica,	at 7 feet depth,	mouth down.

The terminal joints of the great claws of the velvet swimming crab (*Portunus puber*) and the spider crab (*Hyas araneus*) were also observed.

Collections of shells, made by some of the members of the Committee and by the workmen, were submitted to Mr. David Robertson, of Millport, for examination, together with samples of the clay in boxes. His thorough knowledge of the organic remains found in the Scottish shelly clays has been of invaluable service to the Committee, and at their request he has prepared a separate report on the materials which passed through his hands. All geologists interested in these researches will cordially appreciate the value of his special contributions to this report.

With the sanction of Sir Archibald Geikie, the Director-General, Mr. James Bennie, of the Geological Survey of Scotland, made a collection of organic remains from the uppermost 6 feet of the shelly clay, the list of shells being determined by Mr. Sharman, palæontologist to the Geological Survey of England, and revised by Mr. Robertson.

4. *Gravel underlying shelly clay.*—This deposit, which was pierced to a depth of 10 feet in the 'main pit,' is of a yellowish brown colour, and of a coarse, unequal quality. The sand in this gravel is coarse-grained, differing from the fine sand above the blue clay and from the sandy matrix of the overlying boulder clay. The deposit is in some parts roughly stratified. The stones vary in size from fine gravel to blocks 6 or 7 inches across, while a few measure 14 inches in diameter. The largest block, composed of Old Red Sandstone, measuring 21 inches by 20 inches by 8 inches, occurred from 2 to 3 feet below the bottom of the shelly clay. It was flat-shaped, subangular, and in the pit dipped to the southwest at an angle of about 40° or 45°.

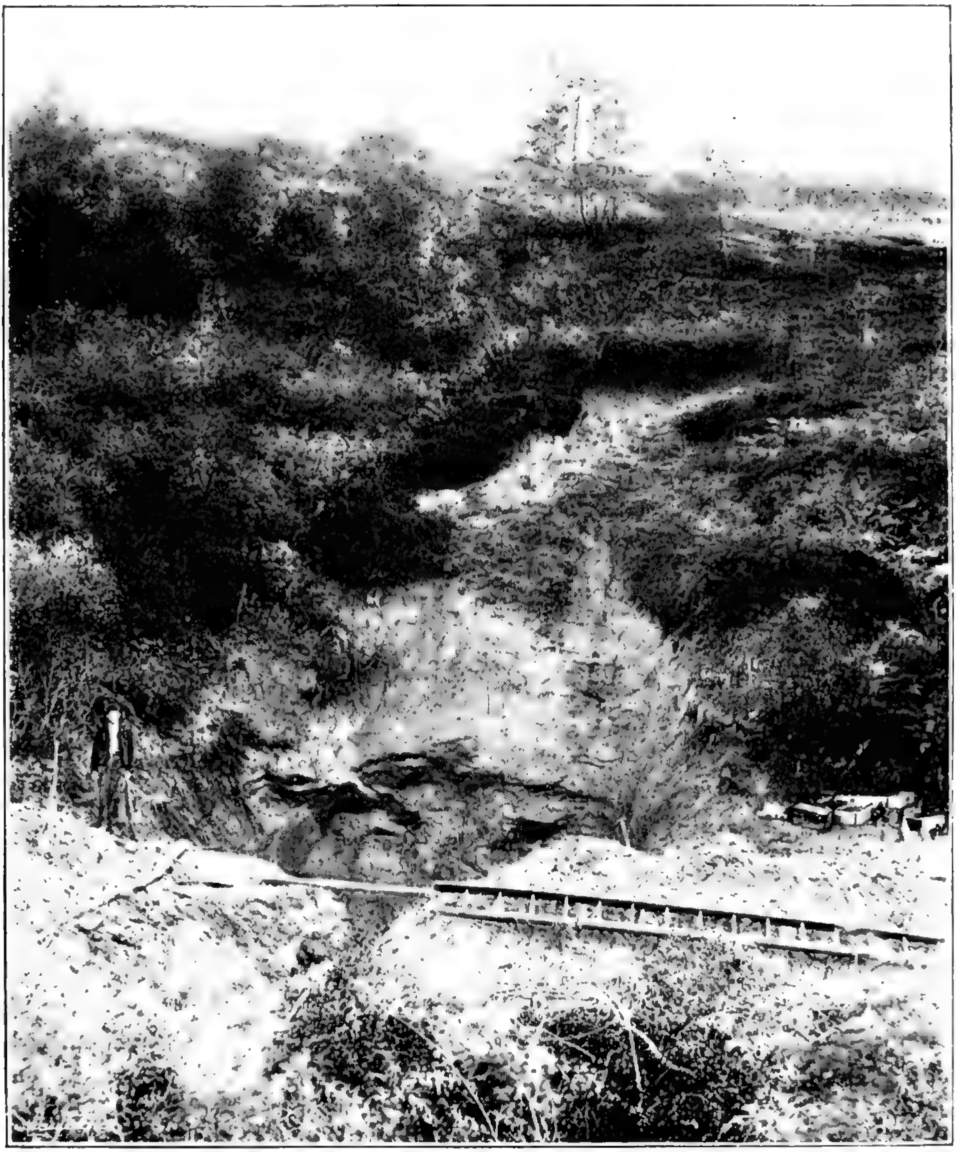
On referring to the table of percentage of stones it will be seen that there is a wide difference in the proportion of the blocks of Old Red Sandstone found in the underlying gravel from that met with in the shelly clay. Indeed the percentage of Old Red blocks in the underlying gravel approaches very nearly to that found in the overlying sandy boulder clay. The blocks of Old Red Sandstone in the gravel were wholly of local origin; a few were striated, most of them were rough and angular on the edges, and several of the flagstone type were highly decomposed. In like manner the blocks of granite and micaceous gneiss closely resemble similar rocks *in situ* in the neighbourhood.

Before closing the 'main pit' two successful photographs of the section were taken by Mr. Whyte, of Inverness, at the request of the Committee, one at a distance of 40 yards and the other near the edge of the pit (see Plates II. and III.).

B.—*Small Excavation* 160 *yards S.W. of the 'Main Pit.'*

The Committee made a small excavation on the south bank of the Cassie Burn, 160 yards south-west of the 'main pit,' at the base and west end of the great section of boulder clay already described, which revealed a thin layer of shelly blue clay at a height of 512 feet above the sea-level. The deposit there exposed was only 15 inches thick: it yielded some of the shells found in the 'main pit,' including *Astarte*, *Natica Grœnlandica*, *Leda pernula*, &c., and Foraminifera.

Here the shelly clay was underlain by 10 inches of hard brown clay, the latter resembling the deposit found on the bank of the Cassie Burn, 233 yards south-west of the 'main pit,' to which we may now briefly refer.

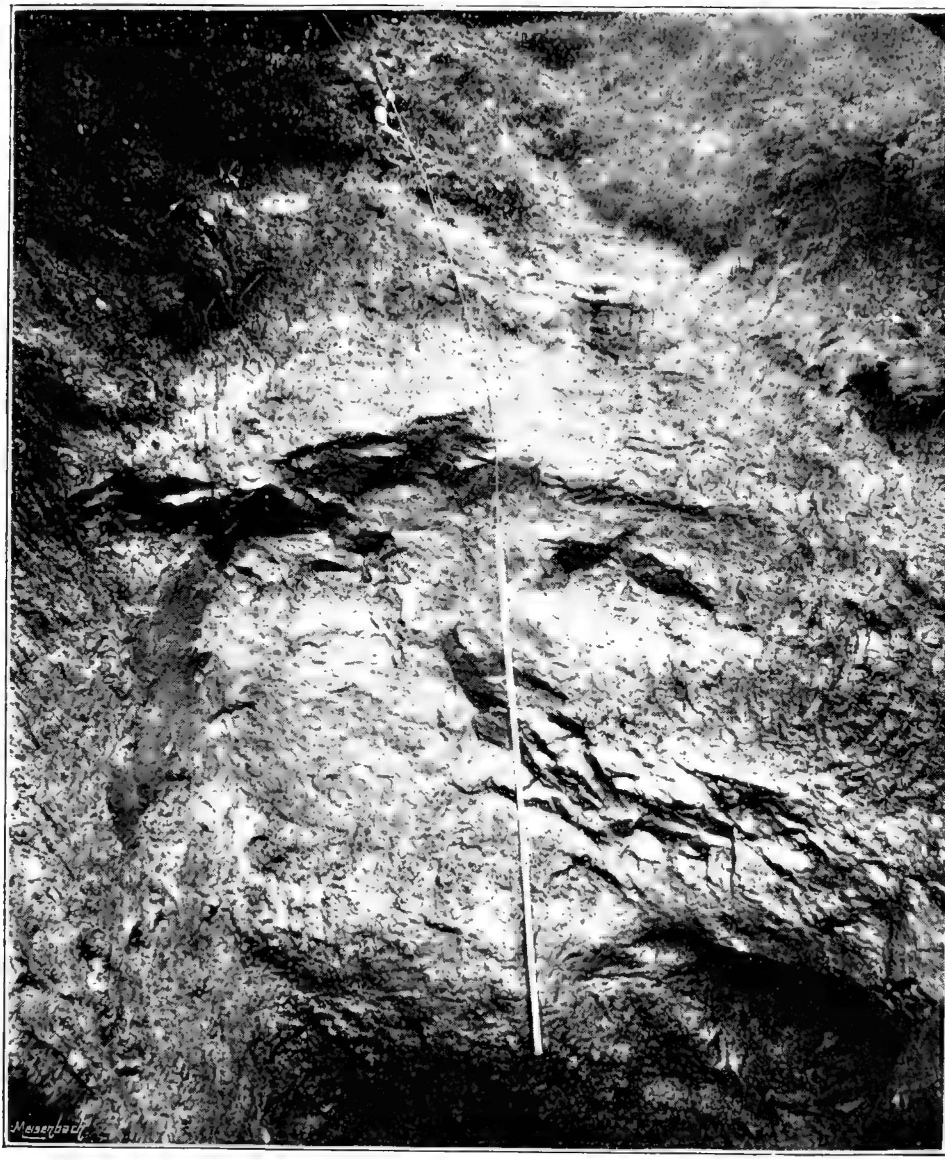


NO. 1.—GENERAL VIEW OF MAIN SECTION.

ABOUT 40 YARDS FROM FACE OF CLIFF, CASSIE BURN, CLAVA.

(From a Photograph.)

Illustrating the Report of the Committee on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other localities.



NO. 2.—VIEW OF SHELLY CLAY, NEAR EDGE OF MAIN PIT, CLAVA.

(*From a Photograph.*)

The bottom of the shelly clay is at the bottom of the 15 *feet measuring staff, and the top is about* 18 *inches above the top of the staff.*

Illustrating the Report of the Committee on the Character of the High-level Shell-bearing Deposits at Clava, Chapelhall, and other localities.

At this latter locality (233 yards S.W. of the 'main pit') a mass of fine hard brown clay is exposed at the foot of the cliff, rising to a height of 8 or 9 feet above the stream, and $523\frac{1}{2}$ feet above sea-level. For a depth of 6 or 7 feet it is entirely free from stones, but at the level of the burn a few occur, though very small. Though no organic remains have been found in this deposit, and though it differs in colour from the typical shelly clay of the 'main pit,' some of the Committee are inclined to regard it as belonging to the same formation. The chemical analysis of the material is interesting. It was found by Mr. W. Ivison Macadam, Edinburgh, to contain 31 per cent. of ferric oxide, and slightly over 1 per cent. of aluminic oxide. 'It is not a clay, strictly speaking, but a sand bound together by iron.' [1]

Clava Shell-bed.—Percentages of stones from the lowest 6 ft. of shelly clay, and from the highest 9 ft. of gravel below the shelly clay, and also from boulder clay above shelly clay, from lists written to Mr. Horne's dictation on the ground.

Description of Stones	Shelly Clay,—Lowest 6 ft.	Gravel below Shelly Clay			Boulder Clay above Shelly Clay	
	Stones from 1 to 6 in. diam.	Stones about 3 in. diam.	Stones from 6 to 9 in. diam.	Stones mostly above 9 in. diam.	Stones of 3 in. diam.	Stones from 6 to 12 in. diam.
Micaceous gneiss	59	$24\frac{1}{2}$	$19\frac{1}{2}$	18	26	14
Quartzite, quartz-schist, and mica-schist.	$12\frac{1}{2}$	7	$1\frac{1}{2}$	—	6	—
Granite	$10\frac{1}{4}$	8	$3\frac{1}{2}$	—	8	10
Old Red Sandstone	17	$53\frac{1}{2}$	$72\frac{1}{2}$	82	56	76
Diorite	$1\frac{1}{4}$	2	$1\frac{1}{2}$	—	—	—
Felsite	—	2	—	—	2	—
Pegmatite	—	1	—	—	2	—
Limestone	—	1	—	—	—	—
Sundries	—	1	$1\frac{1}{2}$	—	—	—
Total	100	100	100	100	100	100

C.—*Boring Operations.*

On reaching the depth of 10 feet below the shelly clay in the 'main pit,' the Committee found that they could not carry the excavation further down without timbering the trench; and this could not be safely done so close to the cliff. Being desirous of reaching the solid rock near the site of the main section, and also of proving the horizontal extension of the shelly clay, they resolved to make a series of bores. For this purpose they employed Mr. Pollock, an experienced mineral borer from Airdrie.

The accompanying ground plan on the scale of 325 feet to the inch shows the relative positions of the various bores. In fixing the sites the object of the Committee was to prove the extension of the shelly clay along the south bank of the Cassie Burn. Two bores were put down

[1] *Trans. Geol. Soc. Edin.*, vol. iv. Part ii.

between the 'main pit' and the small exposure of the shelly clay 160 yards south-west of the 'main pit.' Other bores were put down to the north-east of the 'main pit,' to prove the extension in that direction.

The borer's 'Journal,' stating the nature of the materials with the respective thicknesses, is given in a tabular form below. Mr. Fraser, who made the levelling observations in connection with the work carried out by the Committee, determined the height of the surface of the ground at each bore. He has added columns to the borer's 'Journal,' showing the total depths of the respective deposits and the total heights above sea level. He has also given the distance of each bore from No. 1 bore at the 'main pit.'

Journal of Bores put down at Clava.

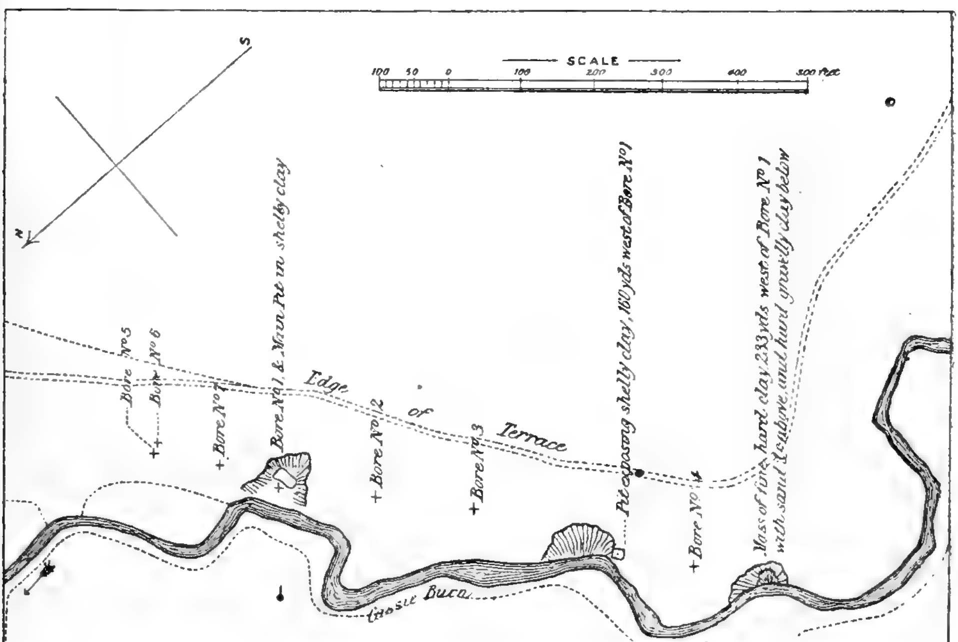
	Depth	Total Depth	Heights above sea
	Ft. In.	Ft.	Ft.
No. 1 *Bore*—[at main pit]	—	Surface	495
Turned earth	2 0	2	493
Dark-blue sandy clay	7 0	9	486
Rough gravel and sandy clay	15 0	24	471
Brown clay and stones	21 6	$45\frac{1}{2}$	$449\frac{1}{2}$
Soft brown conglomerated sandstone	1 9	$47\frac{1}{4}$	$447\frac{3}{4}$
Total depth	47 3	—	—
No. 2 *Bore*—[132 ft. south-west of Bore No. 1]	—	Surface	$511\frac{4}{10}$
Soils (surface)	1 0	1	$510\frac{4}{10}$
Sand and a little fine gravel	15 0	16	$495\frac{4}{10}$
Dark-blue sandy clay	4 6	$20\frac{1}{2}$	491
Total depth	20 6	—	—
No. 3 *Bore*—[275 ft. south-west of Bore No. 1]	—	Surface	$522\frac{3}{4}$
Surface soil	1 0	1	$521\frac{3}{4}$
Hard-bound sand and gravel	22 6	$23\frac{1}{2}$	$499\frac{1}{4}$
Dark-blue sandy clay	4 0	$27\frac{1}{2}$	$495\frac{1}{4}$
Total depth	27 6	—	—
No. 4 *Bore*—[590 ft. south-west of Bore No. 1]	—	Surface	$520\frac{8}{10}$
Surface soil	1 0	1	$519\frac{8}{10}$
Sand and fine gravel	6 0	7	$513\frac{8}{10}$
Rough coarse gravel and sand	18 0	25	$495\frac{8}{10}$
Total depth	25 0	—	—
No. 5 *Bore*—[183 ft. north-east of Bore No. 1]	—	Surface	$505\frac{3}{10}$
Surface soil	1 0	1	$504\frac{3}{10}$
Sand (loose)	6 0	7	$498\frac{3}{10}$
Rough gravel and sand	3 6	$10\frac{1}{2}$	$494\frac{8}{10}$
Brown clay and stones	10 6	21	$484\frac{3}{10}$
Total depth	21 0	—	—

JOURNAL OF BORES PUT DOWN AT CLAVA—*continued.*

	Depth	Total Depth	Heights above sea
	Ft. In.	Ft.	Ft.
No. 6 *Bore*—[183 ft. north-east of Bore No. 1, and 14 ft. south-east of Bore No. 5]	—	Surface	$509\frac{2}{10}$
Surface soil	1 0	1	$508\frac{2}{10}$
Hard-bound sand and a little fine gravel	23 0	24	$485\frac{2}{10}$
Brown clay and stones	6 0	30	$479\frac{2}{10}$
Hard-bound gravel	2 6	$32\frac{1}{2}$	$476\frac{7}{10}$
Total depth	32 6	—	—
No. 7 *Bore*—[90 ft. north-east of Bore No. 1]	—	Surface	506
Surface soil	1 0	1	505
Hard-bound sand	8 0	9	497
Blue sandy clay	2 6	$11\frac{1}{2}$	$494\frac{1}{2}$
Sand and a little fine gravel	3 6	15	491
Total depth	15 0	—	—

NOTE.—The highest part of the shelly clay at the main pit is $503\frac{1}{2}$ ft. above sea-level. The shelly clay at pit 160 yds. south-west of main pit is 512 ft. above sea-level, and the top of the hard clay 233 yds. south-west is $523\frac{1}{2}$ ft.

FIG. 1.—Plan showing positions of Pits and Bores at Clava Shell-bed.



In the course of the boring operations samples of the various materials were preserved and forwarded to Mr. David Robertson for examination for the purpose of comparing them with the materials from the 'main pit.' He has prepared the following report as the result of his investigations :—

FERN BANK, MILLPORT, July 11, 1893.

DEAR SIR,—I have finished the examination of the clays from the bores at Clava taken at different depths. Very few animal remains were noticed. I have given the proportions of the mud, sand, and gravel that each parcel contained, and the relative proportion of the animal remains, and their names. To save repetition in the following list, I may state that the proportion of mud is that which passed through a sieve of ninety-six meshes to the inch, the sand that which passed through a sieve of twenty-four meshes to the inch, and the gravel that which was retained in the same sieve of twenty-four meshes to the inch. I have kept all the materials of each parcel separately, except the muds which passed away in the washing. I have put samples of the sand into small bottles, so that each parcel can be compared with the others. The gravels are parcelled up for the same purpose, so that the different rocks of each can be compared.

The gravels are mostly water-worn, particularly the larger pieces. No striations were noticed on any of the stones, large or small.

The term 'floats' means what is gathered on the surface of the water when the dry clay is put in it and stirred up. In taking the proportions, fractions were omitted or lumped.—Yours very truly,

DAVID ROBERTSON.

BORES OF CLAVA DEPOSIT.

No. 1 *Bore.*—Depth, 9 feet, 'blue clay'; mud, 60 per cent.; fine sand, 24 per cent.; gravel, 16 per cent.

CRUSTACEA.

Order OSTRACODA.—Cytheropteron Montrosiense, Brady, Crosskey and Robertson.

ECHINODERMATA.

Order ECHINOIDEA.—Echinus spine, sp. (fragment).
Spatangus sp. (two whole spines and one fragment).

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Polymorphininæ.* Polymorphina sp. doubtful (one).

Sub-family *Polystomellinæ.* Nonionina orbicularis, Brady (8); Nonionina Boneana, D'Orbigny (2); Nonionina depressula, Walker and Jacob (3); Nonionina stelligera, D'Orbigny (1); Polystomella arctica, Parker and Jones (4).

No. 1 *Bore.*—Depth, 14 to 15 feet; 'rough gravel and sandy clay'; mud, 40 per cent.; sand, 30 per cent.; gravel, 30 per cent.

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Fusulininæ.* Nonionina orbicularis, Brady (3); Nonionina Boneana, D'Orbigny (1); Nonionina depressula, Walker and Jacob (2).

Sub-family *Polystomellinæ.*—Polystomella striato-punctata, Fichtel and Moll. (2).

No. 1 *Bore.*—Depth, 30 and 40 feet; 'brown clay and stones'; mud, 67 per cent.; sand, 12 per cent.; gravel, 21 per cent.

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Polymorphininæ.* Polymorphina oblonga, D'Orbigny (2).

Sub-family *Fusulininæ.*—Nonionina orbicularis, Brady (2); Nonionina stilligena, D'Orbigny (3).

Sub-family *Polystomellinæ.*—Polystomella striato-punctata, F. and M. (1).

No. 1 *Bore.*—Depth, 46 to 47 feet; rock samples 'soft brown conglomerated sandstone'; another parcel of similar character 330 yards north-east of main pit near stream Allt Ruadh.

No. 2 *Bore.*—'Sand and fine gravel' 15 feet thick to bottom of sand; sample from 1 to 16 feet; mud, 25 per cent.; sand, 50 per cent.; gravel, 25 per cent.

In this the proportion of gravel and coarse sand is very great, yet the three largest stones weighed only one ounce.

The 'floats' contained two Foraminifera, Nonionina orbicularis, Brady, and, as usual, a little vegetable matter and mica scales.

There is no certainty that the two Foraminifera belonged to the clay in which they were found, when we consider that we occasionally find in the 'floats' bits of recent plants, some still green, and there are so many ways that such could be carried, on workmen's tools, for example, or on their feet walking over shelly clay.

No. 2. *Bore.*—Depth, 18 to 20 feet; 'dark blue clay'; mud, 50 per cent.; fine grey sand, 24 per cent.; coarse sand and gravel, 6 per cent. One of the stones was half the weight of all the others.

CRUSTACEA.

Order OSTRACODA.—Cythere Dunelmensis, Norman (one valve).

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Polymorphininæ.* Polymorphina lanceolata, Reuss (2).

Sub-family *Fusulininæ.*—Nonionina orbicularis, Brady (common); Nonionina Boneana, D'Orbigny (5); Nonionina depressula, W. & J. (4).

Sub-family *Polystomellinæ.*—Polystomella arctica, P. & J. (rare); P. striato-punctata, F. and M. (common).

No. 2 *Bore.*—Depth, 20½ feet, 'blue clay'; mud, 50 per cent.; fine sand, 38 per cent.; gravel, 12 per cent. (small and mostly angular).

MOLLUSCA.

Family *Littorinidæ.*—Lacuna divaricata, Fabr.; Littorina obtusata, Linn.

CRUSTACEA.

Order OSTRACODA.—Family *Cytheridæ.* Cytheropteron latissimum, Norman (1). Family *Paradoxostomatidæ.*—Paradoxostoma abbreviatum, G. O. Sars (1).

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Fusulininæ.*—Nonionina orbicularis, Brady (rare); Nonionina Boneana, D'Orbigny (rare); Nonionina depressula, W. & J. (rare). Sub-family *Polystomellinæ.*—Polystomella arctica, P. & J. (rare); Polystomella striato-punctata, F. and M. (frequent).

No. 3 *Bore.*—Depth, 23½ feet; brown lumpy clay; requires some force to break it up, but in the dry state it dissolves readily in water; mud, 34 per cent.; sand, 60 per cent.; gravel, 6 per cent.

Floats contain some vegetable matter, amongst it some bits of recent green moss, and one little animal, probably alive when packed in the parcel. Mica scales plentiful; no fossil animal remains noticed.

No. 3 *Bore.*—Depth, 27½ feet; grey clay, dissolved freely in water; mud, 65 per cent.; grey sand, 30 per cent.; gravel, 5 per cent. All very small with the exception of one stone about the size of a boy's marble, spherical, and well polished.

No. 4 *Bore.*—Depth, 7 feet; muddy sand in lumps, brown coloured; dissolved readily in water; mud, 60 per cent.; sand, 24 per cent.; gravel, 14 per cent.

Floats.—No animal remains in the floats.

No. 4 *Bore.*—Depth, 25 feet. All gravel, mostly angular, the largest weighed 4 oz. This sample was so free of mud that it required no washing or looking for fossil remains.

No. 5 *Bore.*—Depth, 9 feet; rough gravel and sand; 'stones and a little small gravel'; the stones are mostly water-worn; one of them is well-rounded and smoothly polished. Like the above it needs no washing.

No. 5 *Bore.*—Depth, 21 feet; 'brown clay and stones.' Brown clay not difficult to break when dry; one little piece, about the size of a small apple, much whiter and greatly harder than the rest. It did not seem to belong to the same bore—the other clay dissolved freely. Mud, 61 per cent.; sand, 24 per cent.; gravel and small stones, 15 per cent., mostly angular.

Floats.—No animal remains.

No. 6 *Bore.*—Depth, 21 to 24 feet; 'hard bound sand and a little fine gravel'; mud, 24 per cent.; sand, 73 per cent.; gravel and coarse sand, 3 per cent.

ECHINODERMATA.

Order *Echinoidæ.*—Echinus spine, one fragment, probably E. Drobachiensis.

Spatangus sp., one spine whole.

No. 6 *Bore.*—Depth, 27 feet; 'brown clay and stones'; the clay dissolved readily in water; mud, 76 per cent.; sand, 16 per cent.; gravel and coarse sand, 8 per cent.

Floats.—Very poor—a few mica scales and a little vegetable matter and one crustacean.

CRUSTACEA.

Order *Ostracoda.*—Schrochilus contortus, Norman.

No. 7 *Bore.*—Depth, 8 to 9 feet; 'hard bound sand'; the first and second portions of the clay of this bore lay over the surface of the blue clay; it

washed nearly all away and was difficult to go through the sieve; mud, 91 per cent.; sand, 6 per cent.; gravel, 3 per cent.; none much larger than a pea.

In this case the clay was washed through a sieve of ninety meshes to the inch: all the others, with the exception of No. 7 bore, were put through a sieve of ninety-six meshes to the inch, which would allow more of the finer portions of the sand to pass through, and give a somewhat higher percentage to the mud.

Floats contained a little vegetable matter, and mica scales, and a few fossil remains.

CRUSTACEA.

Order OSTRACODA.—Cytheridea punctillata, Brady (1).
Family *Polycopidæ.*—Polycope orbicularis, G. O. Sars (1).

RHIZOPODA.

FORAMINIFERA.—Sub-family *Lageninæ.* Lagena sp. (a fragment).

No. 7 Bore.—Depth, 10 to $11\frac{1}{2}$ feet; 'blue sandy clay'; this sample was somewhat bluer than the above, dissolved readily, but more difficult to pass through the sieve; mud, 24 per cent.; sand, 72 per cent.; gravel, 4 per cent.; none of it much larger than a pea.

Floats.—Small in bulk, a little vegetable matter, much mica scales, and a little sand.

CRUSTACEA.

Order OSTRACODA.—Cytheridea papillosa, Bosquet, jun.

RHIZOPODA.

Order FORAMINIFERA.—Sub-family *Miliolininæ.* Miliolina sp. (one imperfect).

No. 7 Bore.—Depth, 14 to 15 feet; 'sand and a little fine gravel'; sample of sand ochre-coloured, when dry adhering much together and taking some force to break it up; dissolved readily in water; mud, 18 per cent.; sand, 78 per cent.; gravel, 3 per cent.

Floats.—A little vegetable matter, a little sand and mica scales; a lump of reddish brown clay, upper part taken 233 yards west of main section; no depth given; bottom part said to contain small round stones; mud, 98 per cent.; fine sand, 2 per cent., with a few grains of coarser sand; no gravel large or small; no organic remains.

Quantities of clays received and examined from Clava bores:—

Bore No. 1	4 parcels	8 lb. in all.
Bore No. 2	3 parcels	$4\frac{1}{4}$ lb. in all.
Bore No. 3	2 parcels	$3\frac{1}{2}$ lb. in all.
Bore No. 4	2 parcels	$3\frac{1}{2}$ lb. in all.
Bore No. 5	2 parcels	$3\frac{1}{2}$ lb. in all.
Bore No. 6	2 parcels	$3\frac{1}{2}$ lb. in all.
Bore No. 7	3 parcels	$6\frac{3}{4}$ lb. in all.

General Results of Boring Operations.

In considering the results obtained by the boring operations we must bear in mind that this method of examination is not so rigidly accurate as excavations from the surface. Even with the most careful manipulation of the tubes it is almost impossible to prevent minute organisms such as Foraminifera being carried down to lower levels from overlying deposits. Again, shells might occur in a bed of clay, and yet the sample of the material brought up by the boring-tube might not yield any traces of such organisms. A remarkable instance of the latter experience may here be adduced. In the case of bore No. 1, which was put down at the edge of the 'main pit,' upwards of 7 feet of the dark blue clay was pierced, and yet not a single shell fragment was found in the sample of this clay sent to Mr. Robertson nor by members of the Committee on the spot, though from direct observation in the 'main pit' we know that shells are met with in this part of the deposit.

Important results were obtained from bore No. 1, which was put down within 5 feet of the edge of the 'main pit.' The solid rock, consisting of coarse pebbly grit of Old Red Sandstone age, was reached at a depth of 45½ feet. Though crushed by the borer's tools the rock was readily recognised as identical with the coarse grit or fine conglomerate found at the foot of the cliff near Allt Ruadh, about 330 yards north-east of bore No. 1. No less interesting is the result that the rough gravel and sandy clay underlying the shelly clay in the 'main pit' was found to rest on 21½ feet of 'brown clay and stones.' The only organisms obtained by Mr. Robertson from the sample of this latter deposit are Foraminifera. From the evidence at their disposal the Committee do not feel justified in forming a definite opinion regarding this deposit.

In bore No. 2, 44 yards south-west of bore No. 1, the blue shelly clay was reached at a depth of 16 feet, or 495½ feet above sea-level. The sample yielded fragments of the following shells: *Lacuna divaricata* and *Littorina obtusata*, with Ostracoda and Foraminifera.

In bore No. 3, 92 yards south-west of bore No. 1, dark blue sandy clay was pierced at a depth of 23½ feet, which was recognised in the field as bearing a close resemblance to the typical blue grey clay of the 'main pit.' Curiously enough, no organic remains seem to have been recorded from the sample examined by Mr. Robertson.

The blue clay was not found in bore No. 4 at a depth of 25 feet. Had funds permitted the Committee were anxious to try a deeper bore on the cliff further south.

At a distance of 61 yards, north-east of bore No. 1, a trial bore, No. 5 did not encounter the blue clay. Bore No. 6 was sunk 14 feet further up the face of the cliff, and though again the typical blue clay was not met with, interesting results were obtained. In the hard-bound sand, at a depth of 21 to 24 feet, spines of *Echinus* and *Spatangus* were met with, while in the hard brown clay and stones (depth 27 feet) one crustacean was found.

The final bore, No. 7, was sunk 30 yards north-east of bore No. 1: it pierced the blue clay at a depth of 11½ feet from the surface, the thickness of the deposit amounting to 2½ feet. It yielded Ostracoda and Foraminifera, while similar organisms were met with in the overlying 'hard-bound sand' at a depth of from 8 to 9 feet.

Extent of Shelly Clay.—From the excavations and trial bores it would appear that the shelly clay is continuous for a distance of 190 yards along the south-east bank of the Cassie Burn—viz., from bore No. 7, situated 30 yards north-east of bore No. 1, to the small excavation 160 yards south-west of the 'main pit.'

The Committee regret that, owing to the cost of these trial bores, they were unable to determine the thickness of the blue shelly clay in each bore. Had funds permitted they would have traced the extension of the deposit in the area north of the Cassie Burn and other directions.

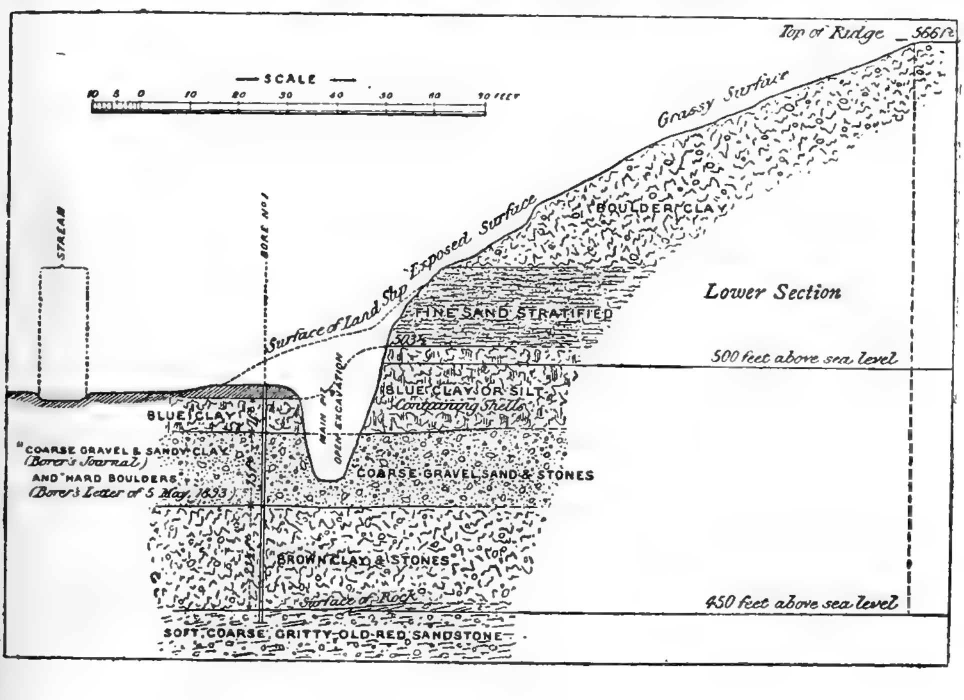
Section at 'Main Pit' to Solid Rock.

By tabulating the results (1) of the excavation at the 'main pit,' (2) of bore No. 1, and (3) the section on the cliff above the 'main pit,' the Committee are able to construct the following section, showing the sequence of deposits at this locality:—

	Feet
1. Surface soil and sandy boulder clay	43
2. Fine sand	20
3. Shelly blue clay with stones in lower part	16
4. Coarse gravel and sand	15
5. 'Brown clay and stones'	$21\frac{1}{2}$
6. Solid rock, Old Red grit	—

The accompanying section, drawn to a scale of 48 feet to an inch, shows the above result in diagram form:—

FIG. 2.—Section at 'Main Pit,' Clava, to Solid Rock.



V.—Direction of Ice-flow in the Neighbourhood of Inverness.

The direction of the ice-flow in the neighbourhood of Inverness is obviously of great importance in relation to the question referred to the Committee. They have drawn up a list of striæ based on observations made partly by Mr. Horne in the course of his survey of the district, which are here given with the sanction of the Director-General of the Geological Survey, and partly by Mr. James Fraser. One instance west of Ethie has been noted by Mr. Hugh Miller. With the view of presenting these observations in a clearer form they have prepared a striæ map of the district extending from Cromarty in the north to Croachy in Strathnairn in the south (fig. 3).

List of Striated Rock Surfaces near Inverness, represented on the Striæ Map.

In Black Isle.

Direction of Ice-flow, E. 25° N.—*Locality.*—On gneiss 500 yards S.S.W. of Upper Ethie farmhouse, about $3\frac{1}{2}$ miles S.S.W. of Cromarty. Height above sea over 600 feet.

Direction of Ice-flow, E. 10°–12° N.—*Locality.*—On Old Red Sandstone in old quarry near stone circle, 500 yards south-west of Mains of Belmaduthy. Height about 400 feet.

Direction of Ice-flow, E. 3° N.—*Locality.*—On Old Red Sandstone, 300 yards north-west of Avoch House. Height about 300 feet.

Direction of Ice-flow, E. 23° N.—*Locality.*—On Old Red Conglomerate at roadside, about 300 yards west of ninth milestone from Dingwall, near Arpafeelie. Height 165 feet.

Direction of Ice-flow, E. 30° N.—*Locality.*—On Old Red Conglomerate at north-east corner of Mains of Drynie farm steading. Height 310 feet.

Direction of Ice-flow, E. 12° N.—*Locality.*—On Old Red Conglomerate, 100 yards north-east of Drumderfit farmhouse. Height 400 feet.

South Side of River Ness, Firth of Inverness and Moray Firth.

Direction of Ice-flow, E. $38\frac{1}{2}$ N.—*Locality.*—On Old Red Sandstone about half-a-mile west of Loch Ashie, at the side of the road from Duntelchaig to Dares. Height about 750 feet.

Direction of Ice-flow, E. 32° N.—*Locality.*—On Old Red Sandstone, about $\frac{3}{4}$ mile south-west of Essich farmhouse. Height about 600 feet.

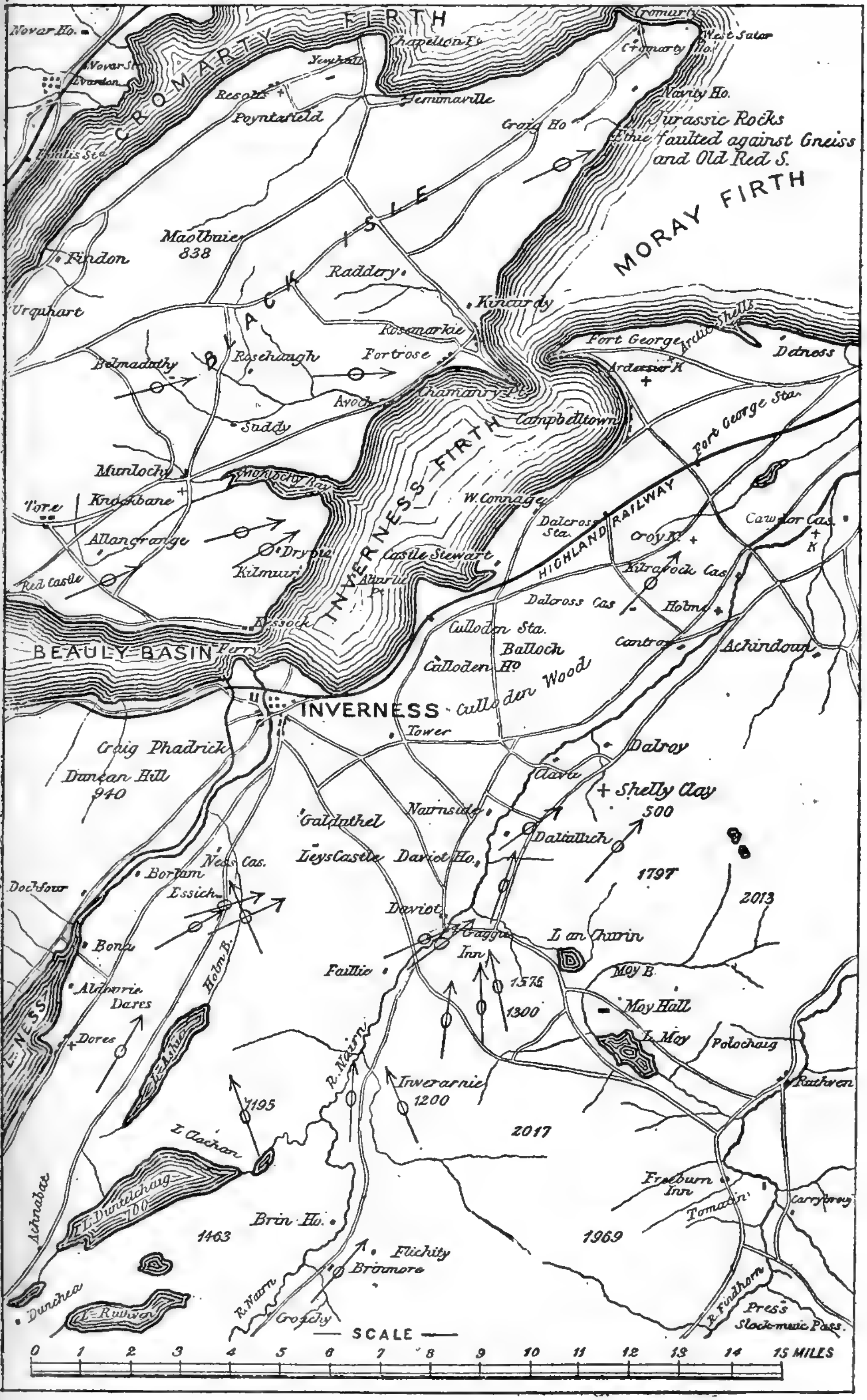
Direction of Ice-flow, E. 13° N.—*Locality.*—On Old Red Sandstone at old quarry, 600 yards S.S.W. of Essich farmhouse, on end slope of hill, 4 miles S. by W. of Inverness. Height 540 feet. (The valley of the Ness widens out eastward at Essich.)

Direction of Ice-flow.—

N. 5° W. N. 38° E.	cross-striæ	*Locality.*—All these instances occur on a dip slope of Old Red Sandstone, measuring 6×5 yards, east bank of Holm Burn, 1,160 yards E.S.E. of Essich farmhouse, and 400 yards south of Fir Plantation at Balvonie of Leys. Height 550 feet.
N. 2° W. E. 22° N.	cross-striæ	
N. 41° E.		
N. 6° to 28° W.		

Direction of Ice-flow, N.E.—*Locality.*—On Old Red Sandstone in Hillhead Quarry, about a mile E.S.E. of Dalcross station. Height 150 feet.

FIG. 3.—Map of Striæ showing direction of Ice-flow near Inverness.



Direction of Ice-flow, E. 5° N.—*Locality.*—On granite at Newton of Park, Kinsteary, 2 miles S.S.E. of Nairn. Height about 150 feet.

Direction of Ice-flow, E. 9°–12° S.—*Locality.*—On granite 200 yards south of Park, and about $2\frac{1}{2}$ miles S.S.E. of Nairn. Height 266 feet.

Direction of Ice-flow, E. 13°–17° S.—*Locality.*—On granite, about 400 yards south of Park and over $2\frac{1}{2}$ miles S.S.E. of Nairn. Height about 230 feet. (The last three instances are east of the limits of the striæ map.)

On Low Grounds in the Nairn Valley.

Direction of Ice-flow, E. 30°–33° N.—*Locality.*—On basic igneous rock at Mains of Daltullich, $4\frac{3}{4}$ miles E.S.E. of Inverness. Height 600 feet.

Direction of Ice-flow, N. 20° E.—*Locality.*—On gneiss $\frac{1}{4}$ mile north-east of Craggie Inn. Height 650 feet.

Direction of Ice-flow, E. 36° N.—*Locality.*—On gneiss south of river, 600 yards S.S.W. of Daviot Bridge. Height about 550 feet.

Direction of Ice-flow, E. 22° N.—*Locality.*—On gneiss north of river, about 100 yards north of Faillie Bridge. Height about 150 feet.

Direction of Ice-flow, N. 7° E.—*Locality.*—On gneiss near south side of river, nearly opposite Beachan farm, or 700 yards north-west of the Free Church of Daviot. Height about 600 feet. (Not on map, being near the next observation.)

Direction of Ice-flow, N. 3° E.—*Locality.*—On gneiss, 300 yards S.W. by W. of the Free Church of Daviot. Height about 650 feet.

Direction of Ice-flow, N. 39° E.—*Locality.*—On gneiss, west end of Creagan-an-Tuirc, close to Brinmore farmhouses. Height 720 feet.

On High Levels in the Nairn Valley.

Direction of Ice-flow, N.E.—*Locality.*—On granite 1 mile N.N.W. of Beinn Bhuidhe Mhor. Height about 1,200 feet.

Direction of Ice-flow, N.—*Locality.*—On granitic gneiss on south shoulder of Beinn-a-Bheurlaich, nearly 2 miles south-east of Faillie Bridge. Height about 1,230 feet.

Direction of Ice-flow, N. 10° E.—*Locality.*—On gneiss at south of Creagan-Bad-Each, $1\frac{3}{4}$ mile S. 14° E. from Faillie Bridge. Height about 1,050 feet.

Direction of Ice-flow, N. 20° W.—*Locality.*—On gneiss on top of Meall-Mōr above Inverarnie, 1,100 yards east of Daviot Free Church at Farr. Height about 1,200 feet.

Direction of Ice-flow, N. 20° W.—*Locality.*—On gneiss near top of Creag-a-Chlachain, about $\frac{3}{4}$ mile north of the outlet of Loch Duntelchaig. Height about 1,100 feet.

From the foregoing evidence it will be seen that on the high grounds between Moy Hall and Faillie in Upper Strathnairn the striæ point on an average due north; a fact ascribable to the ice moving seawards from the elevated range between the Nairn and the Findhorn; while further to the south-west, near Inverarnie and Loch Duntelchaig, the direction is N. 20° W. Near the river course from Croachy to Craggie the trend of the ice-markings is more or less parallel with the course of the valley, or on an average N. 32° E. In the neighbourhood of Essich, near Loch Ness, the trend varies from E. 13°–32° N. In the tract between Loch Ness and Cawdor Castle striæ are not easily found owing to the more or

less continuous covering of superficial deposits; but in Hillhead Quarry, near Dalcross station, the direction is N.E.; and further on, at Kinsteary, south of Nairn, from E. 5° N. to E. 17° S. (see list of striæ).

Proceeding northwards to the Black Isle the striated surfaces between Beauly Firth and Munlochy Bay clearly prove that the trend of the ice-flow varied from E. 12°–30° N. Near Avoch the direction of the ice-markings is E. 3° N.; while near Ethie, about three miles south of Cromarty, it is E. 25° N.

So far as the striæ are concerned the evidence points to the conclusion that the land ice that passed over Clava did not previously traverse the Beauly or Moray Firths. It would appear that the ice which glaciated that portion of the Nairn Valley came from the Great Glen, and from the mountains to the S.E. of the loch towards the sources of the Findhorn, and at some stage of the Ice-age may have traversed part of the bed of Loch Ness in its onward march.

Transport of Boulders.—In the reports of the Boulder Committee of the Royal Society, Edinburgh, it is stated that boulders of the well-known foliated granite of Dirriemore, west of Ben Wyvis, are 'scattered abundantly all over the Black Isle.' They 'have been carried across, not only the ridge of the Black Isle, but what is now the Moray Firth, to beyond Elgin, and they may be seen on the coast between Burghead and Lossiemouth.' [1] They have been found near the Enzie post-office, but none so large as those dug out during the excavations for the Buckie Harbour.[2] The fine-grained pinkish granite of Abriachan on the west side of Loch Ness occurs in the gravel of Tomnahurich near the town of Inverness, 'and eastwards of this point, on beyond Nairn and Forres, it is found less in large boulders, though it occurs in considerable masses, than as forming part of the gravel deposits which are so marked a feature on the south shores of the Moray Firth.' [3] It is further stated that boulders of the 'liver-coloured conglomerate,' which occurs *in situ* between Inverfarigaig and Loch Duntelchaig, are distributed 'over the country between Loch Ness and Lossiemouth.' Cumberland's Stone on Culloden Moor, the boulders named Tomriach on the bank of the Nairn, near Cantraydoun, and Clach-na-Cailliche, near the top of the Hill of Urchany, south of Nairn, are stated to have been derived from this area, the general distribution of these conglomerate boulders being to the N.E. of Caisteal-an-Duin-Riabhaich, near the junction of the Stratherrick and Dores roads, onwards to Elgin.[4] The grey granite of Stratherrick 'is found in blocks of different sizes, some of them large, all over the country east towards Elgin, intermingled with the conglomerate just mentioned.' 'It is also found in blocks scattered on the very top of the ridge of conglomerate between Loch Ceò-Glas and Loch Ness.' [5] It is further recorded that boulders of the gneiss of Stratherrick and the Monadhliath Mountains are found in Strathnairn, near the Free Church of Farr, Farr House, near Flichity, and again further down the valley below Daviot, not far from the mansion of Nairnside.[6]

From the foregoing evidence it is inferred 'that the general direction of movement of these blocks has been eastwards, but chiefly from S.W. to N.E., parallel to the trend of the coast of the Moray Firth at this part.' [7]

[1] See Fifth Report, pp. 68, 69.
[2] See Sixth Report, p. 49.
[3] See Fifth Report, p. 69.
[4] *Ibid.*, pp. 70, 71.
[5] *Ibid.*, p. 72.
[6] *Ibid.*, pp. 72–74.
[7] *Ibid.*, p. 75.

VI. *Report by* Mr. DAVID ROBERTSON, *F.G.S., F.L.S., Mem. Imp. Roy. Zool. Botan. Soc., Vienna.*

The portion of shelly clay from Clava entrusted to me for examination was, with the exception of a small bagful, chiefly in one piece, taken at $2\frac{1}{2}$ feet from the top of the 'main section,' and in a box of broken pieces of stony clay from the bottom of the same section. I had also packages of clay, sand, and gravel from other parts of the deposit, as hereinafter mentioned.

1. The clay in the above-mentioned bag, being taken from different parts of the section, was considered to be a fair sample of the shelly clay. It consisted of—

90 per cent. mud;
7 „ sand, mostly angular (grey);
3 „ stones.

None of the stones was noticed to be striated; some—chiefly sandstones—were angular; the others were mostly water-worn and well polished. None was much larger than a gooseberry. There may have been a little more sand in this instance, as some of the finer portion may have passed off with the mud. Mica scales were plentiful.

The clay seemed to indicate deposition in still water, showing no traces of strong currents, and containing few stones, and those mostly small in size.

2. The shelly clay, 160 yards south-west of the 'main section,' consisted of—

82 per cent. mud;
16 „ sand (grey);
2 „ stones.

The stones were water-worn. No striation was detected.

3. The sand in a tin box, taken from $2\frac{1}{2}$ to 3 feet above the shelly clay of the 'main section,' was in lumps requiring some force to break, and was still harder when dry. It consisted of—

34 per cent. mud;
64 „ light-coloured fine sand;
2 „ per cent. stones.

None of the stones exceeded the size of a pea.

The sand is very fine, mixed with a few small stones. No marine organisms were detected in it. On the whole, it had much the character of blown sand. It was much lighter in colour than the sand washed out of the shelly clay, and contained little or none of the dark mica prevalent in the latter.

4. The stony clay, being bottom part of the shelly clay, near west end of 'main section,' consisted of—

48 per cent. mud;
24 „ sand, with many red grains;
28 „ stones.

These stones were water-worn. No striation was noticed.

In this stony clay six Foraminifera and one Ostracod were obtained. Independently of the finding of Microzoa, I was doubtful whether this was part of the shelly clay, or had got mixed with it, or whether an error had occurred in some other way. To make sure of this point another portion was prepared, and here Foraminifera were still more

numerous, and a few Ostracoda were also found, leaving no doubt that they belonged to the deposit.

5. The gravel (in second tin box) taken from 2 feet below the shelly clay, at east end of the 'main section,' was prepared in the usual way, and lost little by washing. The stones were all well water-worn, with the exception of the sandstones, most of which appeared to have been subjected to little or no rolling. A few rootlets and two Foraminifera were obtained. Although every precaution had been taken to prevent admixture of the materials, still there are many ways in which this might occur, either in the field or during examination.

The sand from this part of the section is of a light yellowish colour, and consists chiefly of small well-rounded particles of quartz with some light grains of mica, derived apparently from the adjacent Old Red Sandstone. In these respects it closely resembles the sand which *overlies* the shelly clay, and differs in a marked degree from that contained in the shelly clay itself, which, as already mentioned, is dark or dark-grey in colour, and contains much black mica, apparently derived from the disintegration of gneissose rocks.

Remarks.

The deposit in all its aspects, taken in connection with its high level, is very puzzling. Although its Arctic character is well established, it differs much from any of the post-Tertiary clays that have come under my notice, particularly in respect of the small variety of fossil organic remains found in it, there being very few remains of echini, star-fishes, worm-tubes, crab-claws, or polyzoa, which are common in the post-Tertiary clays, both on the east and west coasts of Scotland.

The shells, with the exception of those that are young and friable, are fairly well preserved, and show no marks of rubbing or polishing, so far as I could discover. They are chiefly of shallow-water species ; some may have lived in from fifteen to twenty fathoms, but nearer the shore as well ; and the great majority are undoubtedly of littoral species.

With regard to the physical characteristics of the deposit, the following points seem worthy of notice :—(1) The fineness of the sand overlying the shelly clay, and its freedom from stones or gravel ; (2) the generally rounded and water-worn appearance of the stones in the clay, and the small proportion of sand accompanying them ; and (3) the difference in appearance and composition between the sand in the shelly clay and that occurring both beneath and above it, and the fact of the different parts of the deposit—clay, sand, and overlying boulder clay—being so sharply defined from each other.

The question comes to be, Have the shells lived and died where they are found ? After considering all the evidence that has come under my own observation I am strongly inclined to believe that they did live and die where they are found. If we suppose that a transportation of the deposit has been effected by ice action, it is difficult to see how the stones could be so free from striation, or the sand overlying the shelly clay so fine and so free from stones (those found in it being not much larger than a pea), or how the different strata of the shelly clay, the sand, and overlying boulder clay could be laid down so sharply defined, the one over the other, if crushed up to their present position by ice in any form.

DAVID ROBERTSON.

List of Organisms from

—	Mr. Fraser's List (1882) and Remarks		Mr. Bennie's List (1893)	Mr. Robert- (a)	Mr. Robert- (b)
					I. MOL-
Lamellibranchiata:					
Astarte compressa, *Mont.*	*	One specimen			*
Astarte sulcata, *Da Costa*		—		*	*
Axinus flexuosus, *Mont.*		—		*	
Cardium edule, *Linn.*	*	A small fragment			
Leda pernula, *Müll.*	*	Several	*	*	*
Leda pernula, var. mucilenta, *Steenst.*	*	One and a valve			*
Leda pygmæa, *Münst.*	*	One		*	*
Lepton nitidum, *Turton.*		—		*	
Mytilus edulis, *Linn.*	*	Numerous fragments		*	*
Nucula tenuis, *Mont.*	*	A few specimens	*		*
Tellina Balthica, *Linn.*	*	Three or four, and fragments	*		*
Tellina calcarea, *Chem.*			*	*	*
Gasteropoda:					
Buccinum undatum, *Linn.*	*	Fragments of several	*		*
Fusus antiquus, *Linn.*		—		*	
Homalogyra atomus, *Phil.*	*	One example			
Littorina littorea, *Linn.*	*	Most plentiful species	*	*	*
Littorina rudis, *Maton*	*	Two specimens	*	*	*
Natica Grœnlandica, *Beck*	*	Moderately common		*	*
Pleurotoma turricula, *Mont.*	*	Three specimens	*	*	*
Pleurotoma nobilis		—	*		
Pleurotoma Trevelyana, *Turton*	*	One, half grown	*		
Trochus helicinus, *Fabr.*		—		*	*
Trochus Grœnlandicus, *Chem.*		—		*	*
Trophon clathratus, *Linn.*	*	One, in pieces			
					II. CRUS-
Decapoda:					
Crab claws, *sp.*		—			*
Cirripedia:					
Balanus balanoides, *Linn.*	*	Rare	*	*	*
Balanus crenatus, *Brug.*	*	Small and rare		*	*

NOTES.—Those in Mr. Fraser's list were identified by Mr. Jamieson and Mr. vol. iv. p. 136, and *Trans. Inverness Sci. Soc.*, vol. ii.). With regard to *Mytilus*, Mr. but no whole specimens could be found, and fragments were mostly thrown away.'

Shelly Clay at Clava.

son's Lists and Remarks (a) From upper part of main section	(b) From various parts of section	Habitat
LUSCA.		
—	Two fragments .	Arctic and North British, low water to 45 fathoms.
One small valve and two or three larger fragments	Valves, moderately common	Northern and British seas, 7 to 25 fathoms.
One.	—	British seas, in comparatively shallow water.
—	—	Common, all European shores, tides to a few fathoms.
One small valve and a few larger fragments	Rare and small .	Arctic and northern seas, 10 to 80 fathoms.
—	A few valves .	Arctic and northern seas, less common.
One entire and a few valves	Rare . . .	Arctic and northern seas, 20 to 80 fathoms.
A few imperfect valves .	. . . . .	Norwegian and British, not very common, 10 to 90 fathoms
A small fragment . .	One fragment .	All climates, common, high water to a few fathoms.
—	A fragment, small	Northern and British seas, local, 5 to 100 fathoms.
—	Two imperfect valves	Northern and British seas, common, tides to 50 fathoms.
Fragments of valves .	A small fragment .	Arctic, no longer British.
—	A few fragments, and one imperfect	Arctic and British, common, tides to deep water.
One, young . . .	—	Northern and N. British, 20 to 40 fathoms.
—	—	Common on sea-weeds just beyond low water.
Many; the prevailing shell	Very common .	All sea-shores, abundant, between tide marks.
Two	Two . . .	Nearer high-water mark, common.
A few	Common . .	Arctic, rare in British seas, low water to 60 fathoms.
A few	Three small . .	Northern and N. British, low water to 60–100 fathoms.
—	—	Northern and N. British, low water to 60–100 fathoms.
—	—	Northern and N. British, low water to 60–100 fathoms.
A few	—	British and Northern, common, near low water.
A few	—	Arctic and N. British, local, low water to 40 fathoms.
—	One whole and one imperfect	Arctic and British seas, 5 to 70 fathoms.
ACEA.		
—	Three . . .	
Two plates	A few plates, and on stones	Common on stony shores.
A few plates and a small cluster attached to a stone	Rarer, mostly on stones	Common on stony shores in deeper water.

obertson from parcels of the clay sent them at the time (see *Trans. Edin. Geol. Soc.*,
raser notes that 'fragments large and small were plentiful during the recent workings;
he above species are all common in the Glacial clays of the West of Scotland.

List of Organisms, by Mr. D. Robertson—(continued).

II. CRUSTACEA.

Ostracoda.

Species	Remarks	In Clava Clay	Distribution	Fossil
*†**Cythere angulata**, *G. O. Sars* (C. angula, *Brady*, Mon., p. 377)	Sparingly met with in the British seas, N. and W. coasts of Scotland at considerable depths	Rare	Scotland, Norway, Davis' Straits	Scotland, England (Bridlington), Ireland (Portrush).
†**Cythere concinna**, *Jones* (Cythereis clavata, *G. O. Sars*)	Common round British coasts, low water to 50 or 60 fathoms (Irish Channel, &c.)	Common	Norway, Spitzbergen, Davis' Straits	England (Bridlington), Scotland, Ireland, Norway, Canada.
†**Cythere confusa**, *Brady* and *Norman* (C. pellucida, *Brady*, Mon., p. 397)	Moderately common, British coasts, low water to 60 fathoms. Sometimes in brackish water	Moderately rare	Norway, Holland, Mediterranean	Scotland, Ireland (Belfast, estuarine; Portrush, raised beach).
†**Cythere Dunelmensis**, *Norman; Brady*, Mon., p. 416 (C. horrida, *G. O. Sars*)	Moderately common, British coasts, from 4 fathoms to greater depths	Moderately common	Norway, Spitzbergen	England (Bridlington), Scotland (common), Ireland (Belfast, &c.).
Cythere Jonesii, *Baird; Brady*, Mon., p. 418 (C. spectabilis, *Sars*; C. subcoronata, *Brady*)	Moderately rare on British coasts, 2 to 60 fathoms	Rare	Norway, Spitzbergen, Bay of Biscay	Ireland (Belfast, docks) England (Pliocene, Suffolk).
Cythere limicola, *Norman* (C. nodosa, *G. O. Sars*; C. arceolata, *Brady*)	Rather rare, from low water to 25 or 30 fathoms	Rare	Scotland, Norway, Baffin's Bay	Scotland, Canada.
* **Cythere lutea**, *Müller* * (C. viridis, *Brady*, Mon., p. 397)	Common, British coasts, littoral and laminarian zones; also up river estuaries	Rare	Norway, Greenland, Iceland, Mediterranean	Scotland (Belfast, estuarine), Iceland, Norway, Canada.
*†**Cythere pellucida**, *Baird* * (C. castanea, *Brady*, Mon., p. 27)	A shallow water, brackish form, common in the English fens and round the British coasts	Moderately rare	Norway, Holland, Naples	Cardiff (New Dock), Scotland.
Cythere quadridentata, *Baird* (C. quadridentata, *Brady*, Mon., p. 413)	Moderately rare round British coasts, 20 to 25 fathoms	Rare	Norway, Bay of Biscay	Scotland (Loch Gilf).
Cythere tuberculata, *G. O. Sars; Brady*, Mon, p. 406 (C. clathrata, var. lyrata, *Brady*)	Moderately common, British coasts, from 4 to 40 fathoms	Common	Norway, Greenland, Iceland, Gulf of St. Lawrence	Scotland, England, Wales, Ireland.

†**Cythere globulifera**, *Brady* † (Dunelmensis, *Norman*)	Extremely rare in recent state	Rare	Norway, Spitzbergen, Cape Fraser	Scotland (Paisley, Elie Errol), England (Bridlington), Canada.
†**Cytheridea papillosa**, *Bosquet; Brady*, Mon., p. 423 (C. Bradii and debilis, *Norman*)	Moderately common, Irish Channel and Belfast Lough	Rather rare	Norway, Davis' Straits, Iceland	Scotland, England, Norway, Canada.
*†**Cytheridea punctillata**, *Brady*, Mon., p. 424 (Cyprideis proxima, *G. O. Sars*)	Moderately common, British coasts and off Valentia, Ireland	Common	Norway, Iceland, Messina	Scotland, England, Ireland, Sicily.
†**Cytheridea Sorbyana**, *Jones*	Rare; in northern seas	Rare	N. of Scotland, Norway, Spitzbergen	Scotland, Norway, Canada.
*†**Cytheropteron latissimum**, *Norman, Brady*, Mon., p. 448 (C. convexum, *G. O. Sars*)	Moderately common all round British coasts	Common	Holland, Norway, Iceland, Spitzbergen	Scotland, England (Bridlington), Norway, Canada.
*†**Cytheropteron nodosum**, *Brady*, Mon., p. 448	Moderately common, Scotland and England	Moderately common	Norway, Bay of Biscay	British Isles, Canada, Norway.
†**Cytheropteron punctatum**, *Brady*	Moderately common, W. and N. of Scotland, Ireland, Norway	Rare	Norway to Bay of Biscay	British Isles, Norway.
Cytherura nigrescens, *Baird; Brady*, Mon., p. 440	Common all round British shores and estuaries, near mouths of rivers	Rare	Norway, Holland, Bay of Biscay	Scotland, England, Ireland, Norway, Canada.
†**Cytherura similis**, *G. O. Sars* (C. Sarsii, *Brady*, Mon., p. 442)	Moderately rare, Scotland and England, at from 3 to 40 fathoms	Rare	Norway, Smith Sound, latitude 78° 57′ N.	Scotland, Ireland, Norway.
* **Cytherura striata**, *G. O. Sars*	—	Rare	—	Scotland (Cartsdyke, Kyles of Bute, &c.).
†**Cytherura undata**, *G. O. Sars* (C. humilis and undata, *Brady*; C. humila, *Norman*)	Common all round the British coasts	Rare	Holland, Norway, Spitzbergen	Scotland, Ireland, Norway, Canada.
Eucythere declivis, *Norman; Brady*, Mon., p. 430 (E. argus, *G. O. Sars*)	Moderately common at moderate depths in British seas	Rare	Bay of Biscay, Norway, Gulf of St. Lawrence	Scotland, S. Wales, Ireland, Norway, Canada.
Loxoconcha guttata, *Norman; Brady*, Mon., p. 436 (L. granulata, *G. O. Sars*)	Moderately common all round British coasts	Rare	Norway, Bay of Biscay, Mediterranean	Scotland (Drip Bridge), Sicily.
Polycope orbicularis, *G. O. Sars; Brady*, Mon., p. 171	Rare generally; moderately common in some parts of Firth of Clyde (Rothesay Bay)	Rare	British Isles, Norway, Spitzbergen	Scotland (Paisley, Cartsdyke, Duntroon, &c.).

NOTES.—Those marked * are in Mr. Fraser's list (1882); and those marked † are also in Mr. Bennie's recent list (1893). The references are to Brady's 'Monograph of Recent British Ostracoda' (*Trans. Linnean Society*, vol. xxvi.).

List of Organisms, by Mr. D. ROBERTSON—(continued).

Species	Main Section	West of Main Section	Remarks	
SUB-KINGDOM: ANNULOIDA.				
CLASS: ECHINODERMATA.				
Echinus, sp.	*	—	Two small fragments of spines.	
SUB-KINGDOM: PROTOZOA.				
CLASS: RHIZOPODA ;—FORAMINIFERA.				
Astrorhiza crassatina, *Brady*		*	—	Moderately rare.
Bulimina margina, *D'Orb.*	*		Rare	
Cassidulina crassa, *D'Orb.*	*		Moderately common	
Gypsina globulus, *Reuss.*	*		Rare	
* Lagena hexagona, *Will.*	*		Rare	
* Lagena marginata, *W.* and *B.*	*	*	Moderately common	Moderately common.
Lagena marginata, var., *Reuss.*		*	—	Rare.
Lagena Orbignyana, *Seq.*	*		Rare	
†Lagena striata, *Montg.*				
Lagena Williamsoni, *Alcock*	*		Rare	
Miliolina oblonga, *Mont.*	*		Rare	
†Miliolina seminulum, *Linn.*	*		Moderately common	
†Miliolina subrotunda, *Mont.*	*		Rare	
Miliolina venusta, *Karrer*		*	—	Rare.
Nodosaria consobrina, *D'Orb.*	*		Moderately common	
Nodosaria lævigata, *D'Orb.*	*		Rare	
†Nonionina Boueana, *D'Orb.*	*	*	Rare	Moderately rare.
†Nonionina bulloides, *D'Orb.*		*	—	Rare.
†Nonionina depressula, *W.* and *J.*	*	*	Common	Moderately common.
†Nonionina orbicularis, *Brady*	*	*	Common	Common.
†Nonionina stelligera, *D'Orb.*	*	*	Moderately common	Moderately common.
* Polymorphina *acuminata, Will.*				
†Polymorphina angusta, *Egger*				
* Polymorphina *lactea, W.* and *J.*				
†Polymorphina lanceolata, *Reuss.*	*	*	Moderately common	Moderately common.
Polymorphina oblonga, *D'Orb.*	*	*	Moderately common	Moderately rare.
Polymorphina sororia, *Reuss.*	*	*	Moderately common	Moderately common.
†Polystomella arctica, *P.* and *J.*	*	*	Moderately rare	Moderately rare.
Polystomella crispa, *Linn.*	*		Rare	
*†Polystomella striato-punctata, *F.* and *M.*	*	*	Moderately common	Moderately rare.
* *Quinqueloculina seminulum, D'Orb.*				
Rotalia Beccarii, *Linn.*	*		Rare	
Rotalia nitida, *Will.*	*		Rare	
Truncatulina ungeriana, *D'Orb.*	*		Rare	
Truncatulina variabilis, *D'Orb.*		*	—	Rare.
* *Uvigerina angulosa, Will.*				

* In Mr. Fraser's list; † in Mr. Bennie's, as before noted.

Supplementary Note by Mr. Robertson *on the Different Parcels of Clay and their Contents.*

One thing to be borne in mind in examining several parcels of clay from the same deposit is that the contents of any two will scarcely ever be alike.

For example, in my first list (*a*) there are several species of Mollusca not in Mr. Fraser's list, viz.—

Astarte sulcata.
Axinus flexuosus.
Lepton nitidum.
Tellina calcarea.
Fusus antiquus.
Trochus helicinus.
„ *Grœnlandicus.*

On the other hand, in Mr. Fraser's list there are eight species not in my first list, viz.—

Astarte compressa.
Cardium edule.
Leda pernula, var. *mucilenta.*
Nucula tenuis.
Tellina Balthica.
Buccinum undatum.
Pleurotoma Trevelyana.
Trophon clathratus.

Some of these, however, are in my second list (*b*) derived from clay taken from various parts of the section (see preceding table).

State of Preservation.—Many of the delicate shells are whole; yet there are fewer perfect shells, or with the valves together, in Clava than we usually find in the post-Tertiary clays of the Firth of Clyde.

The number of species, also, is notably poorer in the Clava deposit than in those of the Firth of Clyde. For example, *Rissoa striata* and its variety, *R. parva*, are abundant all through the Clyde beds; but, so far as I have seen, they are absent from Clava.

Of course, we have to take into account that the post-Tertiary fauna of the clays on the east coast differ in several respects from those on the west coast. This holds good to some extent also with regard to the fauna of the present seas.

D. R.

Note to Preceding List of Foraminifera.

Note.—The Foraminifera as a class are of very wide distribution both as to latitude and depth, some being found in all seas, and from brackish pools to the deepest soundings. It is worthy of note, however, that some of the genera found at Clava, and a few other Scottish clays, are more restricted in range, being not only 'essentially shallow-water species,' but (as seems more remarkable) to be found chiefly in 'temperate and sub-tropical seas.' The *Rotalia*, for example, 'have not been found within the Arctic or Antarctic circles, but the

genus is represented by one or other of its species in every part of the tropical and temperate zones.' [1] *Gypsina globulus*, again, is chiefly found 'in the coral reefs of warm latitudes,' though 'small examples are occasionally met with on the northern and western shores of the British Islands.' [2] The varieties of *Truncatulina variabilis* also, though 'not entirely confined to shallow water, are commonest at the shallow margins of sub-tropical and temperate seas.' [3]

These species are comparatively rare in our Scottish clays, and it seems interesting to note their occurrence at Clava, where the list, as a whole, is of moderate dimensions.

It may also be pointed out that there are five species of Foraminifera in the list from section 160 yards S.W. which were not met with in the main section; but this is of little consequence, as, if two parcels of clay be taken from the same bed, only a few feet apart, they will seldom be found in all their details exactly alike.

D. R.

Additional Reports and Remarks.

A separate examination of the 'main pit' was made by Mr. T. F. Jamieson, LL.D., of Ellon, who has furnished the Chairman with the following observations as the result of his visit:—

'The extreme thickness of the dark blue clay is about 16 feet. The lowest, 4 or 5 feet, is studded with small pebbles, many of which seem water-worn. The shells are by no means numerous—more scanty than I expected—and seem to be most frequent perhaps at a depth of about 2 feet from the top. At least the *Littorina littorea* appeared to be got oftenest there, and, being a stout shell, it is generally in better preservation than the others, most of which are very decayed and tender, so that they will hardly bear touching. The epidermis, however, is quite visible on most of them, so that there is nothing to countenance the notion that the shells have been ice-borne to their present location. The uppermost 10 or 12 feet of the blue clay is almost quite free from stones, and is a pure silty clay or mud such as might be expected to form on the sea-bottom. It is not at all of the nature of the boulder clay such as we see in Caithness, and I think the probability is that it has been formed where it lies. Had it been transported in a mass from some great distance by the glacier, it would have been more dislocated, and would not occupy such a regular horizontal position beneath the boulder clay, for it is traceable along the base of the bank to a distance of 160 yards southwestwards at about the same level.

'I think, however, that the pressure of the deep mass of boulder clay above, with that of the superincumbent moving glacier, must have occasioned some change in the texture of the clay by consolidating it, and probably causing some degree of movement in its mass. This would account for the crushing of some of the shells and the obliteration of the lamination of the clay and want of any distinct stratification.

'My idea is that after the deposition of the blue clay there had been a subsequent development of land-ice on a great scale.'

T. F. J.

[1] H. B. Brady, '*Challenger*' *Report*, vol. ix.
[2] *Ibid.* [3] *Ibid.*

A Note has also been received from Mr. P. F. Kendall, who was unfortunately prevented from visiting the excavation, but who examined a sample of the shelly clay from the 'main pit.'

'I have examined a portion of the silty clay sent, and so far have found a large number (relatively) of fry of *Nucula* or *Leda*, several small (almost to be called fry) *Littorinas*, probably *L. littorea*, and several *Foraminifera* and *Ostracoda*. The condition of the specimens is perfect, and, judging from that alone, I should be disposed to say that the silt is—though not necessarily *in situ*—a portion of a sea-bottom. I do not give any positive opinion, but that is my impression.'

'I say not necessarily *in situ*, and without an opportunity of seeing the section, I am indisposed to pronounce a more decided opinion. Apart, however, from the character of the matrix and contents, the general facts connected with the locality, the uniqueness of the deposit, and its limited extent are, in my judgment, strongly against the supposition of its being in place; and masses of sea-bottom, with perfectly preserved shells and microzoa, are known to have been carried by land-ice to considerable distances.'

P. F. K.

VII. Summary of the Evidence and General Conclusions.

1. The highest part of the shelly clay in the 'main pit' is 503½ feet above sea-level. The deposit is 16 feet thick in that section, and appears to be continuous for a distance of at least 190 yards in a well-nigh horizontal position.

2. It contains a small proportion of stones, usually well-rounded, and chiefly near the base, varying considerably in relative proportion from those in the overlying boulder clay and underlying gravel. Amongst them is a small block of Jurassic grit; the nearest point where such rocks occur *in situ* is about twelve miles due north of Clava, near the Sutors of Cromarty.

3. The shells are chiefly shallow-water species; some might have lived at depths varying from 15 to 20 fathoms or in shallower water nearer the shore, but the majority are littoral forms. Though the fauna is not intensely Arctic, it implies colder conditions than the present, there being a considerable number of Arctic species common in the Glacial beds in the west of Scotland. The variety of shells is limited, and there is an absence of certain marine organisms, often plentiful in those beds.

4. The shells on the whole are remarkably well preserved, many retaining their epidermis. They are neither rubbed nor striated, differing in this last particular from those found in the shelly boulder clay of Caithness and Orkney.

5. From the assemblage of organic remains and their mode of occurrence, it would appear that the deposit is a true marine silt, or, in other words, a portion of an ancient sea-bottom. If the deposit is not *in situ*, then we can only suppose it must have been transported in mass to its present position.

6. The direction of the ice-flow in the surrounding district, as proved by the striæ and transport of boulders, seems to point to the conclusion that the land-ice which passed over Clava did not previously cross any

part of the *existing* sea-floor. If we suppose that the deposit was transported from Loch Ness, then, so far as we can see, we should postulate a limited submergence in Glacial time to permit of the accumulation of marine beds in that basin.

7. The pressure of the ice that formed the overlying 45 feet of boulder clay would be sufficient to account for the crushing of certain shells, the compression of the annelid tubes, and the production of the system of cracks in the clay referred to in the report.

8. Notwithstanding certain obvious difficulties, the majority of the Committee are strongly inclined to infer, from the assemblage of organic remains and their mode of occurrence, the proved extension of the bed and its apparently undisturbed character, that the shelly clay is *in situ*, indicating a submergence of the land to the extent of over 500 feet. A minority of the Committee, however, do not consider the evidence sufficient to establish this conclusion, or at all points in harmony with it. A note embodying their views is appended.

9. The Committee suggest that they should continue their investigations with regard to the shelly clays at Chapelhall, near Airdrie, and Tangy Glen, near Campbeltown, both occurring underneath boulder clay, and adduced as evidence of submergence in Glacial time.

For the Committee, JOHN HORNE, *Chairman*.

VIII.—APPENDIX.

Note by a Minority of the Committee.

While we have no wish to emphasise any difference of opinion among the members of Committee, we gladly avail ourselves of the opportunity of stating our views afforded us by the courtesy of our esteemed Chairman, whose desire to deal fairly with all sides of the question has been conspicuous throughout this investigation.

As Mr. Robertson has remarked in his valuable report, this Clava deposit 'is in all its aspects a very puzzling one.' Any theory regarding its origin or mode of formation seems to be beset with difficulties. On the one hand, if we conclude that it is really in place as part of an ancient sea-bottom, and so indicates a submergence of over 500 feet, then it is hard to account for the absence, not only of shell-beds, but of all other traces of the sea over the country generally at a similar level, and at hundreds of intermediate levels down to that of existing tides. If this be a clear case of a former sea-bed, it seems strange that it should be the only one known or visible at a similar elevation in Scotland, if we exclude that at Chapelhall, near Airdrie, which is now generally believed to be not *in situ;* while the shelly sands and gravels in the north-east of Aberdeenshire (at 200 to 350 feet or thereby) are also admitted to be quite inconclusive as evidences of submergence. The sea leaves many and various tokens of its presence where it has actually been. It seems difficult to believe that a 'second glaciation,' or any other assignable cause, could remove *all* such traces from hundreds of localities all over the country—from sheltered bays, and glens, and inland curves of land, which would then be occupied by the sea—and yet leave those that are found (at Clava and Chapelhall, if these *are* true instances) in the very tract, as can be shown, of the most powerful ice-sheets.

It is difficult also to see how the 'upper boulder clay,' said to have been formed by the 'second,' or post-submergence, glaciation could fail to be thickly charged, in almost every locality, with remains of marine organisms derived from the miles upon miles of former sea-bed over which the ice must have passed.

From what we know of the configuration of the district and of its glaciation we are convinced that, owing to the immense pressure of ice from the mountains to the west, and the blocked condition of the Moray Firth and the North Sea during the Glacial period, ice on a great scale, issuing from Loch Ness, was deflected eastwards along the base of the Monadhliath mountains; that this deflection began at a considerable distance south of the present mouth of the loch; and that such ice passed over Clava. This conclusion is supported by the striæ and the distribution of boulders throughout the Nairn valley, and on towards Forres and Elgin. The striæ on some higher parts of the Monadhliath hills pointing north, north-west, &c., we view as belonging to an earlier stage of the glaciation, before the congestion in the Moray Firth took place.[1] Unless the different stages and changes of direction of the ice-sheets as they reached their maximum be kept in mind, we submit that a 'map of striæ' of almost any district is unintelligible.

The ice-transport theory, therefore (whatever difficulties may attach to it), has at least this point in its favour, that the deposit is quite in the track of ice which would almost certainly pass over part of a former sea-bed in its progress.[2] It has also this other point, that the shelly clay consists almost wholly of materials derived from some distance, differing from those in the immediate neighbourhood, and from the boulder clay and gravel both above and below it. Further, though the clay itself suggests deposition in deep and comparatively still water, the shells and other organisms it contains are almost entirely of littoral species; and though the stones in it are in general rounded and water-worn, some distinctly striated are associated with them, and all occur promiscuously imbedded in this fine unstratified clay without, as a rule, even a streak of accompanying sand or gravel.

Mere 'submergence' seems inadequate to account for these facts. And we venture to say that to assume, first, a submergence of over 500 feet, then a re-elevation to about the old level, with a return of glacial conditions, much the same as before, is to hang an immense series of changes upon the (as regards interpretation) more or less doubtful evidence before us.

Our observations have convinced us, generally, that no such submergence, nor any at all approaching to it, took place in any part of the British Isles during the Glacial epoch.

On the other hand, we freely admit that the extent of the shelly clay in this instance and the perfectness of many of the contained shells do weigh against the supposition that the deposit, as a whole, owes its transport, or at least its present form, to land-ice. The objection from the comparatively perfect condition of the shells is perhaps the most important. Whether, in view of the known instances in which even

[1] These striæ may partly belong also to a later time *after* the congestion had given way, but for various reasons we are disposed to assign them mainly to the earlier stage.

[2] A submergence of only 60 feet would make Loch Ness an arm of the sea, with a long, comparatively shallow bay at its seaward end.

delicate shells have been transported uninjured by ice, this objection be insuperable must be left to the judgment of others. Our own feeling is that if the case depends mainly on this point it is impossible to pronounce upon it with confidence.

On the whole, our opinion, with all deference, is that we have not yet reached a solution of the difficulties connected with the Clava deposit.

D. B.
P. F. K.

Erratic Blocks of England, Wales, and Ireland. Twenty-first Report of the Committee, consisting of Prof. E. HULL, (*Chairman*), Prof. J. PRESTWICH, Dr. H. W. CROSSKEY, Prof. W. BOYD DAWKINS, Prof. T. McK. HUGHES, Prof. T. G. BONNEY, Mr. C. E. DE RANCE, Mr. P. F. KENDALL (*Secretary*), Mr. R. H. TIDDEMAN, Mr. J. W. WOODALL, *and* Prof. L. C. MIALL.—*Drawn up by* Mr. P. F. KENDALL (*Secretary*).

THE Committee were appointed, as in former years, for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the erratic blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation.

The Committee have again to acknowledge the valuable assistance rendered by the Yorkshire Boulder Committee and the Glacialists' Association, as well as by independent observers. The work of organisation has been prosecuted and several districts are being investigated in a manner that promises to yield results of the highest value. The Corresponding Societies have been invited to co-operate, and a hope is entertained that information will soon be forthcoming from counties regarding which no reports have as yet been presented to this committee. The President of the British Association, Sir Archibald Geikie, LL.D., F.R.S., has, in his capacity as Director-General of H.M. Geological Survey, granted permission to the officers of his staff to report to the Committee erratics observed during the course of their field-work. A valuable and instructive report by Mr. De Rance is the first product of this arrangement. The report records *every* boulder at present visible within the area selected. Similarly exhaustive reports are those by Captain Dwerryhouse, upon the shores of the estuary of the Mersey, and by Miss Shipton and Captain Dwerryhouse, upon the erratics on the Dee shore near Parkgate; in the latter case the observers have compiled an analysis of their list for publication.

The comparison of the lists of Messrs. Dambrill-Davies, Platt, and De Rance on the one hand with those of Mr. Mawby, Captain Dwerryhouse, and Miss Shipton on the other brings out very clearly the much greater relative abundance of Lake District rocks than of those from Scotland, on the eastern side of the plain of Lancashire and Cheshire as compared with the western side of that area. In harmony with this result is the fact that the remarkable list of erratics from the gravels of the Yorkshire Calder contains not a single Scottish rock.

The Committee regret that they have been obliged to publish merely a digest of their very voluminous report, but arrangements are in progress

whereby a type-written copy of the detailed report will be lodged in public libraries in London, Edinburgh, and Dublin. Meanwhile the Secretary will be prepared to furnish any information which is desired.

CHESHIRE.

Alderley District.

Reported by Surgeon-Major W. R. DAMBRILL-DAVIES, *per Glacialists' Association.*

32 L.D. andesites, 1 Coal-measure sandstone, 1 quartzite (?), 3 Scottish granites, 22 L.D. granites, 2 Buttermere granophyres.

Macclesfield District.

Reported by C. E. DE RANCE, Esq., *F.G.S., &c., of H.M. Geol. Survey. (By permission of the Director-General.)*

These 6-in. maps have been marked off into quarters, and each quarter into an eastern and a western half.

SHEET 37: N.W. (West)—12 Buttermere granophyres, 1 L.D. dolerite, 2 L.D. porphyrites, 13 L.D. andesites, 2 Eskdale granites, 3 Scottish granites = 33 *boulders in* 3 *square miles at altitudes of* 600–1,030 *feet above O.D.*

SHEET 37: N.W. (East)—18 Buttermere granophyres, 13 L.D. andesites, 4 Eskdale granites = 35 *in* 3 *square miles at altitudes of* 800–1,255 *ft.*

SHEET 37: S.W. (West)—5 Buttermere granophyres, 4 L.D. andesites, 1 L.D. porphyrite, 4 Eskdale granites = 14 *boulders in* 3 *square miles at altitudes of* 700–1,090 *ft.*

SHEET 37: S.W. (East)—39 Buttermere granophyres, 34 L.D. andesites, 1 L.D. porphyrite, 3 L.D. andesitic agglomerates, 4 Eskdale granites, 8 Scottish granites, 14 granites (? source) =103 *boulders in* 3 *square miles at altitudes of* 760–1,340 *ft.*

SHEET 37: S.E. (West)—6 L.D. andesites, 3 Scottish granites, 6 grits (probably local) = 15 *in* 3 *square miles at altitudes of* 1,060–1,260 *ft.*

SHEET 36: N.W. (West)—1 L.D. andesite, 1 granite, 1 not specified =3 *in* 3 *square miles at altitudes of* 300–350 *ft.*

SHEET 36: N.W. (East)—4 Buttermere granophyres, 8 L.D. andesites, 2 granites (? source) = 14 *in* 3 *square miles at altitudes of* 470–580 *ft.*

SHEET 36: N.E. (West)—3 L.D. andesites = 3 *in* 3 *square miles at altitudes of* 500–556 *ft.*

SHEET 36: N.E. (East)—1 L.D. andesite = 1 *in* 3 *square miles at altitude of* 494 *ft. above O.D.*

SHEET 36: S.W. (West)—5 L.D. andesites, 1 not specified = 6 *in* 3 *square miles at altitudes of* 280–320 *ft.*

SHEET 36: S.W. (East)—2 L.D. andesites = 2 *in* 3 *square miles at an altitude of* 430 *ft.*

SHEET 36: S.E. (West)—1 L.D. andesite, 1 L.D. granite = 2 *in* 3 *square miles at altitudes of* 455 *and* 500 *ft.*

SHEET 36: S.E. (East)—1 L.D. andesite = 1 *in* 3 *square miles at an altitude of* 600 *ft.*

SHEET 44: N.W. (West)—18 Buttermere granophyres, 13 L.D. andesites, 2 Eskdale granites, 1 Scottish granite, 1 granite (? source) = 35 *in* 3 *square miles at altitudes of* 925–1,050 *ft.*

SHEET 43: N.W. (East)—35 Buttermere granophyres, 4 L.D. porphyrites, 16 L.D. andesites, 4 Eskdale granites, 1 Scottish granite, 1 granite (? source), 1 white rock (local), 2 grits (local) = 64 *in* 3 *square miles at altitudes of* 980–1,280 *ft.*

SHEET 44: S.W. (West)—2 L.D. andesites =2 *in* 3 *square miles at altitudes of* 636 *and* 1,198 *ft.*

SHEET 44: S.W. (East) — 1 L.D. andesite. *Altitude* 740 *ft.*

SHEET 35: N.W. (West)— 1 L.D. andesite. *Altitude* 140 *ft.*

SHEET 35: N.W. (East) — 1 L.D. andesite. *Altitude* 206 *ft.*

SHEET 35: N.E. (West)— 1 L.D. andesite. *Altitude* 221 *ft.*

SHEET 35: N.E. (East) — 1 L.D. andesite. *Altitude* 254 *ft.*

SHEET 35: S.E. (West)— 1 L.D. andesite. *Altitude* 246 *ft.*

SHEET 35: S.E. (East) —10 L.D. andesites, 1 Scottish granite. *Altitudes of* 213–260 *ft.*

Disley.

Reported by Dr. GORDON, *M.D., per Glacialists' Association.*

The Avenue, Lyme Park, 1 granite, 1 L.D. andesite.

Report on the Boulders lying on the East Shore of the Estuary of the River Dee, between Burton Rocks on the South and West Kirby on the North, with a comparison with those on the corresponding shore of the Mersey from Herculaneum Dock, Liverpool, to Mersey View Road, Ditton, near Widnes. By Miss LAURA J. SHIPTON *and* Capt. ARTHUR R. DWERRYHOUSE, *of Liverpool (per Glacialists' Association).*

The boulders for the most part lie on the beach between high and low water marks, and are in some cases partially buried in sand and silt. They have been derived from the washing away of the boulder clay cliffs.

The boulder clay extends under the more recent river deposits, and in places crops out through these.

Occasionally boulders are found *in situ* in these outcrops of clay. Their dimensions in inches and their situation together with the direction of the axes and striæ are given below:—

(1) Adesite 25 in. × 24 in. × ?; sub-angular; planed; striated; striæ N. 10° W.; near Rifle Targets, Neston Collieries.

(2) Silurian[1] grit 15 in. × 8 in. × 5 in. (+); sub-angular; planed; striated; striæ N. 12° W.; about middle of sea wall, south of Parkgate.

(3) Andesite[1] 15 in. × 9 in. × 6 in. (+); sub-angular; planed; striated; striæ N. 12° W.; near last.

(4) Granite,[1] Criffel, 17 in. × 12 in. × 4 in. (+); sub-angular; planed; striated; striæ N. 11° W.; near last.

(5) Silurian grit 23 in. × 20 in. × 6 in. (+); sub-angular; planed; striated; striæ N. 12° W.; an embayment of sea wall about 40 yds. south of the promenade, Parkgate.

[1] Surrounding Nos. 2, 3, and 4 are a number of small ones, partly embedded in boulder clay, and evidently *in situ*, and all having their upper surfaces approximately in the same horizontal plane. These are all striated in the same direction, viz., N. 12° W., and constitute a striated pavement similar to those described by the late Mr. D. Mackintosh (*Q.J.G.S.*, vol. xxxv. p. 434), and by Mr. J. Lomas, A.R.C.S., and one of the present writers (*Trans. Liverpool Geol. Soc.*, pt. i. vol. vii. 1892–93).

(6) Andesite 44 in. × 31 in. × 20 in. (+); sub-angular; striated axillary; striæ N. 10° W.; opposite sea wall, south of Gayton Cottage, near Heswall.

(7) Andesite 40 in. × 19 in. × 12 in. (+); sub-angular; axis N. 5° W.; north of Gayton Cottage.

(8) Local sandstone 14 in. × 12 in. × ?; sub-angular; axis N. 5° W.; near last.

(9) Diabase 40 in. × 20 in. × 12 in. (+); angular; axis N. 10° W.; north of boathouse between Heswall and Thurstaston.

(10) Granite, Criffel, 20 in. × 14 in. × ?; sub-angular; planed; striated; striæ N. 12° W.; 200 yards south of old stone culvert and roadway between Thurstaston and Caldy (Dawpool).

The total number of boulders which we have measured and recorded is 1,176 (the full list being deposited with the Glacialists' Association at Stockport), consisting of—

Andesite, Lake District	317	Total Lake District rocks = 548 (exclusive of Silurian grits, some of which may have been derived from Scotland).
Andesitic breccia, &c.	95	
Granite, Eskdale	110	
Granophyre, Buttermere	26	
Granite, Criffel	102	Total Scotch rocks = 134.
Dalbeattie granite	32	
Silurian grit	78	
Diorite (origin doubtful)	92	
Diabase (? Scotch)	286	
Carboniferous sandstone	4	
Millstone grit	2	
Basalt	9	
Volcanic ash	2	
Quartzite	3	
Felsite	6	
Local Triassic sandstone[1]	6	
Various of doubtful origin	6	
	1176	

Size of Boulders.

Nature	Under 3 ft.	3 ft. and over, but under 4 ft.	4 ft. and over, but under 5 ft.	5 ft. and over, but under 6 ft.	Over 6 ft.
Andesite	243	62	9	2	1
Andesitic agglomerate and ash	70	18	7	—	—
Granite, Eskdale	96	10	3	1	—
Granophyre, Buttermere	22	4	—	—	—
Silurian grit	59	14	5	—	—
Granite, Criffel	91	10	1	—	—
„ Dalbeattie	26	5	—	—	1
Diorite	80	10	1	—	1
Diabase	251	26	6	3	—
Carboniferous sandstone	4	—	—	—	—
Millstone grit	1	1	—	—	—
Basalt	8	1	—	—	—
Volcanic ash	—	2	—	—	—
Quartzite	2	—	1	—	—
Felsite	5	1	—	—	—
Local sandstone	6	—	—	—	—
Various of doubtful origin	5	—	—	—	1

[1] There is a very large number of blocks of local sandstone on the shore, but as many of these have formed part of old sea walls and the like, only those which are *in situ* or show undoubted signs of glaciation have been included in the above list.

Under 3 feet	82·4 per cent.
3 feet and over, but under 4 feet	14·0 „
4 feet and over, but under 5 feet	2·8 „
5 feet and over, but under 6 feet	0·5 „
Over 6 feet	0·3 „
	100·0

Form of Boulders, Striæ, &c.

—	Angular	Sub-angular	Rounded	Planed	Striated
	p. c.	p. c.	p. c.	p. c.	p. c.
Andesite	25·2	71·3	3·5	38·1	20·5
Andesitic agglomerate and ash	26·3	68·4	5·3	37·9	21·0
Granite, Eskdale	19·1	77·3	3·6	44·5	12·7
Granophyre, Buttermere	15·4	76·9	7·7	61·5	23·1
Silurian grit	48·7	51·3	0·0	59·0	41·0
Granite, Criffel	19·6	73·5	6·9	38·2	18·6
Granite, Dalbeattie	12·5	87·5	0·0	43·7	0·0
Diorite	31·5	68·5	0·0	20·6	5·4
Diabase	17·8	79·0	3·2	15·7	2·8
Carboniferous sandstone	0·0	100·0	0·0	0·0	25·0
Millstone grit	100·0	00·0	0·0	0·0	0·0
Basalt	33·3	66·7	0·0	0·0	0·0
Ash	0·0	100·0	0·0	50·0	0·0
Quartzite	33·3	66·7	0·0	33·3	33·3
Felsite	66·7	33·3	0·0	33·3	16·7
Local sandstone	33·3	66·7	0·0	50·0	50·0
Various of doubtful origin	50·0	50·0	0·0	33·3	16·7

Summary.

		per cent.		per cent.
Angular	287 =	24·4	Planed	394 = 33·5
Sub-angular	851 =	72·4	Striated	176 = 15·0
Rounded	38 =	3·2		
	1176 =	100·0		

Comparison of the Boulders of the Dee with those of the Mersey.[1]

	Mersey per cent.	Dee per cent.
Andesite	38·87	26·97
Andesitic agglomerate and ash	9·30	8·08
Granite, Eskdale	6·20	9·35
Granophyre, Buttermere	1·97	2·21
Silurian grit	5·07	6·63
Granite, Criffel	6·48	8·67
Granite, Dalbeattie	11·27	2·72
Various Scotch granites	9·58	0·00
Diorite	2·82	7·82
Diabase	1·13	24·32
Carboniferous sandstone	0·00	0·34
Millstone grit	0·00	0·17
Basalt	0·28	0·77
Volcanic ash	0·84	0·17

[1] The figures for the Mersey boulders have been obtained from the lists published in the twentieth report of this committee, and from a list by Capt. A. R Dwerryhouse in the present report.

Comparison of the Boulders of the Dee with those of the Mersey—continued.

	Mersey per cent.	Dee per cent.
Quartzite	0·00	0·25
Felsite	1·13	0·51
Limestone	0·84	0·00
Local sandstone	0·84	0·51
Various of doubtful origin	3·38	0·51
	100·00	100·00

Summary.

	Mersey per cent.	Dee per cent.
Lake District rocks	56·34	46·61
Scotch rocks	27·33	11·39
Diabase	1·13	24·32
Silurian grit	5·07	6·63
Alia	10·13	11·05
	100·00	100·00

The diabase, which is so plentiful in this district, is very scarce amongst the Mersey boulders, and, according to Mr. D. Mackintosh, who speaks of them as *Scottish* greenstones, they are not common in the neighbourhood of Chester ('Q. J. G. S.,' vol. xxxv. 1879, pp. 434–438).

Speaking of Delamere Forest, the same author says: 'Scottish greenstone (with a few exceptions) is absent.'

We have not had an opportunity of comparing the rock with specimens from Scotland, so have not included them amongst the Scotch rocks in the analysis. Considering them as Scotch, the proportions would stand as follows: Lake District, 46·61 per cent.; Scotch, 35·71 per cent.; alia, 17·68 per cent.

This would show a considerable excess of Scotch rocks on the Dee shore as compared with that of the Mersey.

Barnston and Pensby.

Reported by W. Mawby, Esq., *per Glacialists' Association.*

6 L.D. andesites, 1 Yewdale breccia, 1 Silurian grit, 2 diabase, 2 sandstones (local), 1 Scottish granite, 1 Eskdale granite.

Derbyshire.

Note on Boulder Clay and other Glacial Deposits between Chapel-en-le-Frith and Miller's Dale.

Reported by A. Taylor, *per Glacialists' Association.*

In Chapel-en-le-Frith boulders, andesites, granites (and a breccia), &c., are fairly numerous.

Near the east end of the village a bed of boulder clay containing granites, &c., and vein quartz pebbles, is being worked for brick-making. Height about 700 ft.

A boulder with three faces scratched, all from narrow to blunt end, was found on the tramway.

One of granite, 40 in. × 24 in. × 24 in., was found in the brook at Barmoor Clough (800 ft.).

In the face of the cliff overlooking Barmoor Clough, on the right

hand when looking up the clough, I found *in situ* small boulders of granite and andesite with pebbles of local sandstones, well rounded (900 ft.).

At a place about a mile from Doveholes, at a height of about 1,100 ft., I found pebbles of andesite, granite (?), and flints.

From this point to Miller's Dale I found only one foreign boulder; at less than a quarter of a mile from Miller's Dale station there is an andesite boulder built into the wall. Height about 700 ft.

Flintshire.

Vale of Clwyd.

Reported by Messrs. P. F. Kendall *and* J. Lomas, *per Glacialists' Association.*

Craig Fawr, Meliden.—6 L.D. andesites, 1 L.D. ash, 1 porphyrite (? Cheviots), 1 Scottish granite, 2 Scottish grits, 24 Welsh grits, 1 hard slate, 1 gannister, 2 Welsh rhyolites, 1 red micaceous sandstone.

In field under *i* of *Siambue* (map 79 N.W.).—1 Scottish granite, 1 Eskdale granite.

Pandy.—Gravel pit by terminus of mineral railway; Scottish granite, Eskdale granite, Buttermere granophyre, Ailsa Craig eurite; rock very like the Mynydd Mawr rock with riebeckite, many Carboniferous limestones—one bored by Cliona.

Marion Mills.—Many Carboniferous limestone boulders. One *in situ* had the long axis S. 21° W. (true).

Tremeirchion.—In Fynnon Beuno Cave. One hundred boulders taken at random gave 33 grits, 29 Welsh felsites, 14 Carboniferous limestones, 8 Carboniferous sandstones, 4 slates, 2 gannisters, 1 millstone grit, 1 micaceous sandstone, 1 grey quartzite, 1 Triassic sandstone, 2 doubtful, 1 Scottish granite, 3 L.D. andesites; 9 were well scratched.

Near Greenbâch.—5 Buttermere granophyres, 1 Scottish granite, and many Welsh felsites, &c.

Bach-e-graig.—Several Buttermere granophyres, 1 Scottish granite, and many Welsh rocks.

Lancashire.

Decoy Marsh to Mersey View Road, Ditton.

Reported by Captain A. R. Dwerryhouse, *per Glacialists' Association.*

On the shore, Decoy Marsh to Mersey View Road, Ditton: 8 L.D. andesites, 3 Scottish granites, 1 felsite, 1 Silurian grit, 1 Eskdale granite.

In Mersey View Road: 3 L.D. andesites.

In new road from Hale Gate Farm to Mersey View Hotel: 10 L.D. andesites, 2 Eskdale granites, 2 Scottish granites, 1 Buttermere granophyre.

In new road between Hale village and Hale Gate Farm: 1 Scottish granite, 1 Eskdale granite.

Potter's Lane, Halebank: 18 L.D. andesites, 1 L.D. andesitic agglomerate, 1 Silurian grit, 7 Scottish granites, 1 diabase, 2 Buttermere granophyres, 1 Carboniferous limestone, 3 Eskdale granites.

Main road, Garston to Hale. In plantation near Mount Pleasant Farm: 1 L.D. andesite. At entrance to stackyard: 2 L.D. andesites, 1 L.D. andesitic agglomerate, 1 Silurian grit, 1 Scottish granite. At Speke Hall: about 150 stones exceeding 12 in. in diameter include L.D. andesite, Dalbeattie granite, Eskdale granite, Buttermere granophyre, Silurian grit, and 1 diabase. Near Sutton's Farm, Hale Heath: 1 Eskdale granite and 1 L.D. andesite.

Hale Heath, Hale: 8 L.D. andesites, 1 felsite, 3 Silurian grits, 4 Scottish granites, 1 Buttermere granophyre, 1 granite (? source).

Hale village and neighbourhood: 5 L.D. andesites, 5 Scottish granites, 1 Eskdale granite, 1 diorite, 1 felsite.

Hale Wood, Tarbock and Halsnead district: 24 L.D. andesites, 3 L.D. andesitic agglomerates, 1 Coal-measure sandstone, 2 Silurian grits, 8 Scottish granites, 6 Eskdale granites.

Hough Green and neighbourhood: 12 L.D. andesites, 2 L.D. andesitic agglomerates, 2 felsites, 2 Silurian grits, 1 Carboniferous sandstone, 2 Buttermere granophyres, 4 Scottish granites, 6 Eskdale granites.

Manchester (Renshaw Street).

Reported by B. Hobson, Esq., *M.Sc., F.G.S.*

1 granite [a well-marked Galloway type, P. F. K.].

Levenshulme.

Reported by Messrs. Kendall *and* Lomas, *per Glacialists' Association.*

1 dolerite or diabase, 1 Scottish granite, 1 Silurian grit, 2 Coal-measure sandstones containing ferruginous pebbles, 1 unspecified.

The orientation of four was noticed: it ranged from E. $4\frac{1}{2}°$ S. to E. 24° S. (true).

Rochdale District.

Reported by S. S. Platt, Esq., *Assoc.M.Inst.C.E., per Glacialists' Association.*

2 quartz porphyries, 2 granophyres (locality not specified), 17 L.D. andesites, 1 quartz pebble, 1 hæmatite, 5 L.D. rhyolites, 21 Buttermere granophyres, 8 L.D. porphyrites, 8 Eskdale granites, 1 Scottish (?) granite, 1 halleflinta, 1 Silurian grit, 3 L.D. andesitic agglomerates, 1 quartzite, 1 Carboniferous limestone, 1 quartzose grit, 1 local sandstone.

Isle of Man.

Kirkbride.

Reported by the Rev. S. N. Harrison, *per Glacialists' Association.*

6 quartzes, 25 grits, 1 Queensberry grit, 6 Criffel granites, 2 biotite granites, 1 syenite, 4 granites (locality not specified), 1 Shap granite, 3 gneisses, 1 pitchstone, 1 red-based porphyry.

On the shore at Shellag and Cranstal are large numbers of erratics. Out of a group of 100 over 1 ft. 6 in. in diameter more than half were of Criffel granite. The rest were made up of limestones, grits, sandstones, Loch Doone granites, and conglomerate.

Douglas Head, in cutting of Electric Railway.

Reported by T. AXON, Esq., *per Glacialists' Association.*

1 altered Skiddaw slate. Long axis nearly due N. and S.

[This rock is identical in appearance with that of the 'contact zone' round the Dhoon granite.—P. F. K.]

STAFFORDSHIRE.

Hanley: Mousecroft Brickworks.

Reported by W. HAMPTON, Esq., *per Glacialists' Association.*

1 L.D. andesite. Altitude 450, long axis N.W.–S.E.

Hanley: Between New Park and County Cricket Ground.

Reported by F. BARKE, Esq., *per Glacialists' Association.*

In an upper bed of boulder clay: 2 Buttermere granophyres, 2 L.D. andesites, 1 Scottish granite, 1 millstone grit.

Small boulders, chiefly from a lower bed of red boulder clay: 10 Buttermere granophyres, 6 L.D. andesites, 1 L.D. andesitic agglomerate, 4 Eskdale granites, 1 Scottish (?) granite, 8 millstone grits, 1 Bunter pebble.

YORKSHIRE.

(Communicated by the Yorkshire Boulder Committee.)

Valley of the Calder.

Reported by JAMES SPENCER, Esq., *Halifax.*

Luddenfoot: 2 L.D. volcanics. Sowerby Bridge: 1 L.D. volcanic. North Dean: 2 L.D. volcanics, 3 Buttermere granophyres, 1 Eskdale granite. Elland: 4 Eskdale granites, 7 Buttermere granophyres, 1 Eskdale eurite, 9 L.D. volcanics, 1 Carboniferous limestone. Mirfield: 1 Buttermere granophyre.

Reported by JOHN BURTON, Esq., *of Horbury.*

Horbury: 88 Eskdale granites, 22 Buttermere granophyres, 39 L.D. volcanic, 1 red quartzite (? Triassic), 4 vein quartzes, 1 black chert. [It is well to remark here that the rock most commonly found was the Buttermere granophyre, and not the Eskdale granite, as might be inferred from the above analysis.]

Reported by CHARLES W. FENNELL, Esq., *of Wakefield.*

Thornes: 14 Eskdales, 4 Buttermere granophyres, 4 L.D. volcanics, 1 vein quartz. Wakefield: 5 Eskdale granites, 2 L.D. volcanics. Kirkthorpe: 3 Eskdale granites, 3 Buttermere granophyres, 1 L.D. volcanic. Stanley: 3 Eskdale granites, 3 L.D. volcanics. Smalley Bight: 1 L.D. volcanic.

Laithkirk, Middleton-in-Teesdale.

Reported by the Rev. Wm. R. Bell.

11 Shap granites. Mr. Bell remarks that all boulders in his district occur in the valley of the Lune, and none in the Tees. Supposing the boulders to have been borne in on ice from Shap Fell, the mountainous ridge forming the boundary between Yorkshire and Westmorland (Lune Street), at least 1,532 feet high, would have to be crossed; and, as the mountain ridge between Lune Valley and Tees Valley in its eastern part does not rise near so high, it might be supposed that a few boulders would find their way here and there into Teesdale.

Tanfield, near Masham.

Reported by W. Gregson, Esq., *F.G.S.*

1 Shap granite.

Ripon: Lindrick Farm, two miles west of the town.

1 Shap granite.

Topcliffe, near Thirsk.

Reported by T. Carter Mitchell, Esq., *F.S.A.*

1 millstone grit.

York.

Reported by J. E. Clark, Esq., *B.A., B.Sc.*

1 millstone grit.

Skipsea.

Reported by J. W. Stather, Esq., *F.G.S.*

1 dolerite.

Errata.

20th Report, 1892 :—
p. 268, line 30, *for* 'Northam' *read* 'Mortham.'
p. 269, line 26, *for* 'Shap granite' *read* 'Ennerdale granophyre.'

The Present State of our Knowledge of the Zoology of the Sandwich Islands.—Third Report of the Committee, consisting of Professor A. Newton (*Chairman*), Dr. W. T. Blanford, Dr. S. J. Hickson, Professor C. V. Riley, Mr. O. Salvin, Dr. P. L. Sclater, Mr. E. A. Smith, *and* Mr. D. Sharp (*Secretary*).

The Committee were appointed to report on the present state of our knowledge of the zoology of the Sandwich Islands, and to take steps to investigate ascertained deficiencies in the fauna, with power to co-operate with the Committee appointed for the purpose by the Royal Society, and to avail themselves of such assistance as might be offered by the Hawaiian

Government. They have continued to act in concert with the Royal Society Committee, the two having together maintained Mr. R. C. L. Perkins in the islands during the whole of the twelve months since the last report. They have now the pleasure of stating that that gentleman has obtained valuable results in several departments of zoology, and more especially in entomology. The Committee have received from him several consignments, being the result of his first year's work. These are roughly estimated at nearly 150 bird-skins, 3,000 insects, 1,000 shells, a collection of spiders in spirit, together with some crustaceans, worms, and myriapods. These specimens confirm the importance of the investigation your Committee are carrying on, while the information received from Mr. Perkins and other quarters strengthens their belief that the work should be done at once, and that it is not probable that it will be satisfactorily done except by some such body as your Committee.

The Committee therefore request that they may be reappointed, with the same powers as before, and that the sum of 200*l*. be placed at their disposal.

A Digest of the Observations on the Migration of Birds at Lighthouses and Light-vessels, a report on the same.—Report of a Committee, consisting of Professor A. NEWTON (*Chairman*), Mr. JOHN CORDEAUX (*Secretary*), Messrs. R. M. BARRINGTON, J. A. HARVIE-BROWN, W. EAGLE CLARKE, *and the* Rev. E. P. KNUBLEY.

THE Committee have to report that steady progress has been made with the systematic tabulation of the statistics, and a series of schedules framed for the final report. The nature of the work is such that it necessitates a great expenditure of time, as each item contained in the vast mass of schedules accumulated has to be separately dealt with and entered in the sheets. The Committee trust that the Association will reappoint them as before, so that the work, now entrusted to one of their number—Mr. W. Eagle Clarke—may be duly carried out and brought to a conclusion.

The present state of our knowledge of the Zoology and Botany of the West India Islands, and on taking steps to investigate ascertained deficiencies in the Fauna and Flora.—Sixth Report of the Committee, consisting of Dr. P. L. SCLATER (*Chairman*), Mr. GEORGE MURRAY (*Secretary*), Mr. W. CARRUTHERS, Dr. A. C. L. G. GÜNTHER, Dr. D. SHARP, Mr. F. DUCANE GODMAN, Professor A. NEWTON, *and* Dr. D. H. SCOTT.

THIS Committee was appointed in 1887, and it has been reappointed each year until the present time.

During the past year the efforts of the Committee have been directed mainly to the working out of the great series of specimens secured from the West Indian region by means of its collectors, and the collector employed by Mr. Godman.

Zoology.

The list of birds collected in Anguilla by Mr. W. R. Elliott has been published by Dr. Sclater in the 'Proceedings of the Zoological Society.' Mr. R. I. Pocock has completed his account of the Myriapods, Scorpions, Pedipalpi, and Peripatus, and his exhaustive papers on these subjects, which have been communicated to the Linnean Society, are in course of publication. Professors Riley, Ashmead, and Howard have finished the parasitic Hymenoptera of St. Vincent, and their paper, which contains descriptions of about 300 new species, has also been presented to the Linnean Society. These authors have been entrusted with the insects of the same group from Grenada, and a report on them will be duly forthcoming. In last year's report the publication was announced of Herr Hofrath Brunner v. Wattenwyl's 'Orthoptera of St. Vincent.' His paper on the Orthoptera of Grenada has now been received, and is being published by the Zoological Society. It describes fifty-five species, eight of which are new, and thirteen were not met with in St. Vincent. The report on the Hemiptera of St. Vincent, by Dr. Uhler, and a very important memoir on the Ants, by Professor Forel, have also been received, and will be published without delay.

The Rev. Mr. Matthews has undertaken to examine and report upon the Trichopterygidæ and Corylophidæ, and the specimens are now in his hands.

Botany.

Additional collections of cellular Cryptogams from Dominica, made last autumn by Mr. W. R. Elliott, have been received and distributed to those workers who have undertaken the groups of these plants. In addition to those mentioned in last year's report Mr. R. Spruce offered to work out the Hepaticæ of Dominica, and he has completed his examination. About thirty species are new, but for the rest Mr. Spruce finds great resemblance with the Hepatic flora of the adjacent French Antilles. The novelties obtained by Mr. Elliott were mainly from the peaks of the Diablotin and Les Trois Pitons. Mr. William West, of Bradford, is at present engaged on an examination of the difficult and obscure forms of hot-spring Algæ from the Souffrière of Dominica, and Professor Wainio has undertaken the Lichenes. All the groups of cellular Cryptogams have thus either been completed or are in course of examination.

The Committee regard with satisfaction this rapid working out of the vast series of specimens obtained by its efforts, and have considered and approved of a proposal to examine the island of Margarita, the natural history of which is wholly unexplored.

The Committee recommend their reappointment with the following members:—Dr. Sclater (Chairman), Mr. George Murray (Secretary), Mr. Carruthers, Professor Newton, Mr. Godman, Dr. Günther, and Dr. Sharp. They also recommend that a grant of 200*l.* be placed at their disposal to enable them to continue their work, and to adequately provide for the exploration of Margarita.

The Marine Zoology of the Irish Sea.—Report of the Committee, consisting of Mr. GEORGE BROOK, Professor A. C. HADDON, Mr. W. E. HOYLE, Mr. I. C. THOMPSON (*Secretary*), Mr. A. O. WALKER, *and* Professor W. A. HERDMAN (*Chairman*).

[PLATE IV.]

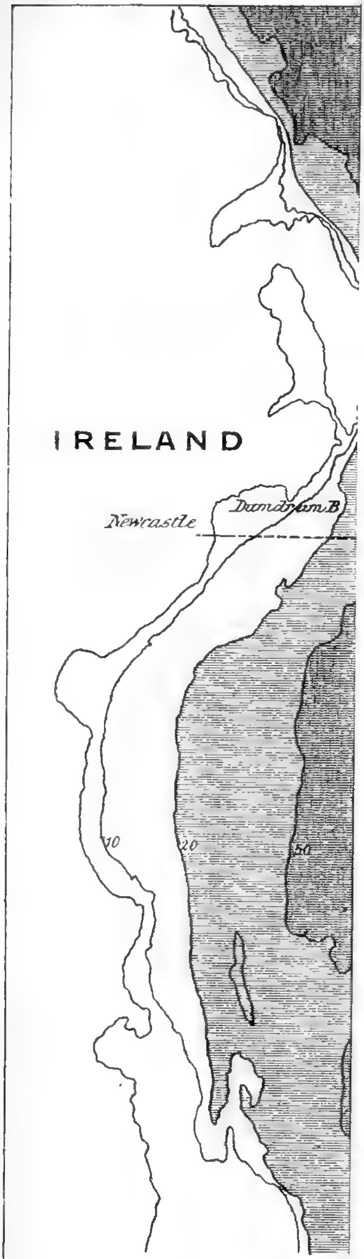
CIRCUMSTANCES have prevented Mr. Brook,[1] Professor Haddon, and Mr. Hoyle from taking much practical part in the work; but the other three members of the Committee have all been present on nearly all the expeditions, and they have received much assistance from their colleagues of the Liverpool Marine Biology Committee and from some of the other naturalists who have been working at the Port Erin Biological Station during this year. The present report is drawn up by the Chairman, with contributions from Mr. Thompson and Mr. Walker, and from other naturalists, in regard to the groups of animals they have severally undertaken to investigate.

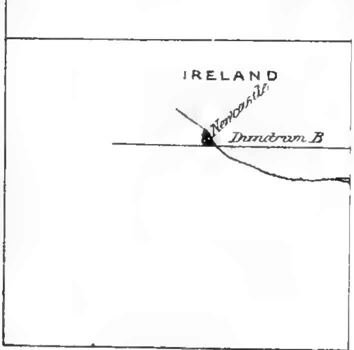
The area which this Committee was appointed to explore is that region of the Irish Sea which lies around the Isle of Man (see chart, Plate IV.), and which is classic ground to the marine biologist as being the scene of the first pioneer work of Professor Edward Forbes more than sixty years ago. Some few parts of the area were also investigated more minutely later on by Forbes in conjunction with Mr. R. McAndrew, a Liverpool merchant well known in science from the extensive dredging operations he conducted from his yacht along the north-west coasts of Europe from the Mediterranean to the north of Norway. The greater part of our area, however, has never been thoroughly explored, and some parts are still unknown ground to the naturalist. It is an interesting region from the considerable diversity of shore, of depth, and of bottom which it presents, and, as your Committee hope to show, it possesses an abundant fauna, including a number of rare and novel forms.

A continuation of the deep-water depression runs down from the Clyde sea area on the western side of the Isle of Man (see chart and section, Plate IV.), and gives depths of 70 to 80 fathoms within 12 miles of land. The bottom of this depression is occupied by a stiff blue-grey clay-mud, in which we find the annelids *Panthalis Oerstedi* and *Lipobranchius Jeffreysii*, the crustacean *Calocaris Macandreæ*, the echinoderms *Brissopsis lyrifera* and *Amphiura Chiajii*, the pennatulid *Virgularia mirabilis*, and the mollusc *Isocardia cor.*

In moderate depths on the sides of the depression we come upon varied bottoms of sand and sandy mud, gravel, dead shells, &c., on which is a rich fauna representing all the usual invertebrate groups. It is from this region that the greater number of our additions to the British fauna have come. On April 30, from a depth of 46 fathoms, we obtained two specimens of *Cyclostrema millepunctatum*, Friele, a species only previously known from a depth of 649 fathoms near the Lofoten Islands in the north of Norway. From depths of 25 to 30 fathoms, to the west of Port Erin, we have obtained in considerable quantity the interesting ascidian *Forbesella tessellata*, which unites, in a

[1] The sudden death of our friend and colleague Mr. George Brook has occurred since this report was drawn up.





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Illustrating the I

Chart showing the area under investigation

Section across the Irish Sea, through Douglas

Illustrating the Report of the Committee on the Marine Zoology of the Irish Sea.

manner which though satisfactory to the evolutionist is aggravating to the orderly systematist, the characters of the Styelinæ and of the Cynthinæ.

The Isle of Man is connected with Lancashire by a broad plateau under 20 fathoms in depth (see chart and section, Plate IV.), to the north and south of which prolongations of the western deeper water extend inwards to the east. A considerable portion of our work has been done in the broad southern extension which lies between Liverpool and the Calf of Man (fig. 1), and gives depths of from 20 to 40 fathoms.

FIG. 1.—Map of the L. M. B. C. District.[1]

C, Calf of Man; D, Douglas; E, Port Erin; H, Hilbre Island; P, Puffin Island; R, Ramsey.

In the shallower water around the coasts there is, of course, very great difference in the physical conditions and in the fauna of different regions; for example, the sandbanks and flat expanses of mud off the Lancashire coast are very different in every way from the more varied ground off the rocky southern shore of the Isle of Man. But even the seemingly uninteresting sandy wastes of Lancashire present many curious facts and problems to the marine biologist. We find that on the estuarine flats round Hilbre Island, as Lindström suspected to be the case on the coast of Gothland some years ago, the very abundant *Hydrobia ulvæ* lays its eggs upon its neighbours' shells, probably as being the largest and most stable objects among the shifting sand-grains around it. And it may also be remarked that this supposed barren region is of immense economic importance as a nursery for young food-fishes.

Liverpool was naturally the headquarters of the Committee, but we took advantage of the presence of the biological station at Port Erin, on the south-west corner of the Isle of Man, to start our dredging expedi-

[1] For the use of the figures illustrating this report we are indebted to the Liverpool Marine Biology Committee.

tions from that point, as it is the nearest land to the most interesting and the least explored ground, and we made use of the laboratory of the station for the first rough sorting-out of our material. As one active member of the Committee, Mr. Walker, lives at Colwyn Bay, on the coast of North Wales, he has been able to supply some information in regard to that end of the district.

The Committee were appointed on August 10. On account of the absence of members nothing could be done during the first month; but they commenced work with a dredging expedition in the hired steam-trawler 'Lady Loch' on September 24, and other expeditions took place on the following dates: November 12, January 29, March 11 to 13, March 29 to April 4, April 28 to May 1, May 19 to 22, and June 17 to 19. It will be noticed that the Committee have carried on their work at sea during the winter months as well as in summer; and although the entire grant of 30*l.*, and a good deal more, has been already spent on these expeditions, they are still continuing the dredgings whenever two or three of the party can be got together, and they hope to undertake a good deal of further exploration during August and September. Notwithstanding the considerable measure of success they have had during the past ten months, the Committee realise vividly that their work is far from complete, and they feel that they are justified, by the results they have already obtained and by the fact that a considerable part of the area, including the deep water lying between the south of the Isle of Man and the north of Anglesey (see chart, Plate IV.), is still unexplored, in asking to be reappointed, with a grant sufficient to enable them to carry on the work for another year.

The following is a short account of the various expeditions:—

I. On September 24 an attempt was made to reach the deep water lying off Port Erin, but the wind was so strong and the sea so heavy that it was found impossible to do any work off the southern and western sides of the island, so the 'Lady Loch' steamed up the east side, and the rest of the day was spent in dredging in the neighbourhood of Laxey at the following localities:

1. Off Clay Head, 17 fathoms: Several hauls, varied bottoms. Amongst the species obtained were—*Polymastia robusta*, *Suberites domuncula*, *Amphilectus incrustans*, *Spongelia fragilis* (large specimens), and a desmacidonid sponge (the *Halichondria expansa* of Bowerbank), which is new to the district, and probably belongs to the genus *Amphilectus*, ten species of hydroids and fourteen species of polyzoa—*Ascidia mentula* (containing *Pinnotheres veterum*), *Lima hians*, and *L. Loscombii*, *Psammobia tellinella*, *Pecten varius*, *Trochus magus*, *Modiolaria marmorata*, and *M. discors*.

2. Off Garwick Bay, 4–12 fathoms: 'Melobesia' bottom, several hauls. Here were obtained *Eudendrium capillare*, *Aglaophenia pluma*, and seven other species of hydroids, several polyzoa, *Ebalia Cranchii*, *Hoplonyx similis*, *Megamphopus cornutus*, and *Podocerus Herdmani*—a new species of amphipod named by Mr. A. O. Walker, who has given the following provisional diagnosis:

'*Podocerus Herdmani*, n. sp.

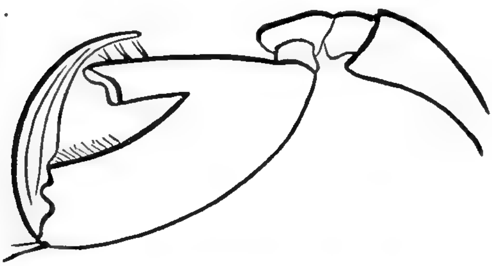
'Allied to *P. falcatus* and *P. minutus*, G. O. Sars, but differing in the "hand" of the second gnathopod of the male, as shown in the annexed figures (fig. 2, p. 529).

'The large tooth which in these species springs from the base of the

hind margin in this species is much shorter, and rises from nearly the centre. There is also a prominent tooth near the centre of the hind margin of the "finger," which is very characteristic. The female resembles *P. minutus.* Length, 3 mm.'

3. Laxey Bay, 8 fathoms, on the 'Zostera' bed: Here were *Campanularia angulata, Membranipora spinifera, Cellepora ramulosa, Pedi-*

FIG. 2.—Second Gnathopod of Male Amphipods.



Podocerus minutus (after Sars).

P. Herdmani, n. sp.

cellina gracilis, and various other hydroids and polyzoa, some compound ascidians, *Cerapus difformis*, and a considerable number of very large living *Pectunculus glycimeris.*

The ascidians dredged in this expedition yielded a number of parasitic copepoda, amongst which were *Botachus cylindratus, Notopterophorus papilio, Doropygus pulex* and *D. poricauda, Notodelphys Allmani*, and *Ascidicola rosea.*

II. On November 12 the dredging was, on account of the weather, confined to the immediate neighbourhood of Port Erin. Along with many common things we found the schizopod *Gastrosaccus sanctus*, not previously known nearer our seas than Jersey.

III. On January 29, 1893, the Committee had the use of the Lancashire sea-fisheries steamer 'John Fell.' Several hauls were taken about 7 miles to the west of Fleshwick (Isle of Man), then some further to the south between Port Erin and the Calf. Amongst other species obtained were *Cliona celata* (fine, in various conditions), *Sertularia tenella*, and a number of hydroids and polyzoa, *Sarcodictyon catenata, Porania pulvillus* and *Palmipes membranaceus, Inachus dorsettensis, Ascidia venosa* and *A. virginea, Capulus hungaricus, Venus casina*, and *Pectunculus glycimeris.*

IV. On March 11–13 the work was again done from the steamer 'John Fell.' On the 11th the steamer left Douglas to examine the shoal lying to the north-east and south of the Bahama light (see chart, Plate IV.). Here, along with various food-fish and some commoner invertebrates, some very large specimens of *Tritonia Hombergi* were trawled; also the ascidians *Ascidia virginea, Didemnum gelatinosum* and *Polycyclus Savignyi* (very large specimens), *Corystes Cassivelaunus, Scaphander lignarius, Aglaophenia tubulifera, A. myriophyllum, Calycella fastigiata,* and *Sertularella Gayi*, which is a new record to the district; *Eudendrium rameum, Thuiaria articulata, Gonothyrœa gracilis* and other zoophytes, and various common polyzoa (very abundant and luxuriant).

On the 13th, after trying again the same shoal as on the 11th, the steamer went to 'the top end of the Hole,' 26 miles east of St. Ann's

Head, 30 fathoms. Here there are sand to the north and mud to the south, and some hauls were taken along the line of junction. Amongst other things the following nudibranchs were obtained: *Tritonia Hombergi*, *Dendronotus arborescens* (up to 5 inches in length), *Eolis Drummondi*, *Eolis rufibranchialis*, and *Eolis Farrani*; also *Virgularia mirabilis* and no less than twenty-five species of hydroid zoophytes and twenty-three species of polyzoa.

V. From March 29 to April 4 the Committee were working from Port Erin, and had the s.s. 'Lady Loch' hired for two of these days. One day was spent in dredging on the rocky bottom round the Calf and near the Chicken lighthouse, and in exploring the caves about Spanish Head and the Stack Rock. These can only be entered in a boat in calm weather at low tide. Their sides and roof are so closely covered with masses of bright red ascidians (*Polycarpa glomerata*), black and white sponges (*Pachymatisma Johnstoni* and *Stelletta Collingsi*), and tufts of *Tubularia indivisa* that scarcely any rock is visible. Amongst the more noteworthy animals dredged round the Calf and obtained on the neighbouring shores were the rare calcareous sponge *Ute glabra*, *Corynactis viridis*, *Hyalinœcia* sp., *Depastrum cyathiforme*, *Lineus gesserensis*, *Dinophilus tæniatus* (breeding at Easter), fifteen species of hydroids, including *Aglaophenia tubulifera*, *Halecium tenellum*, *Lafoea dumosa* form *robusta*, *L. fruticosa*, *Cuspidella costata* and *C. humilis*; the brachiopod *Crania anomala*; the crustacea *Xantho hydrophilus* var. *tuberculatus*, *Ebalia tuberosa* and *E. tumefacta*, *Galathea dispersa* (one with a parasitic Bopyrian), *Spirontocaris spinus* (one with a parasitic Bopyrian), *Janira maculosa*, *Tritæta gibbosa*, *Amphithoe rubricata*, *Aora gracilis*, *Conilera cylindracea*, *Mæra Othonis*, *Metopa* (? n. sp.), and others; the mollusca *Spirialis retroversus*, *Rissoa cingulus*, var. *rupestris*, *Fissurella græca*, *Emarginula fissura*, *Chiton lævis*, *Pleurobranchus plumula*, *Lima elliptica* and *L. Loscombii*, *Astarte sulcata* and *A. triangularis*, *Solecurtus antiquatus*, *Lyonsia norvegica*, *Pecten tigrinus* and *P. testæ*, *Kellia suborbicularis*, *Pandora inæquivalvis*, *Lamellaria perspicua*, *Circe minima* and *Thracia distorta*, the two last being new records to the district; the tunicata *Molgula citrina*, *Styela grossularia*, *Ascidia venosa*, *A. virginea*, and *A. plebeia*, *Botryllus Schlosseri*, *B. violaceus*, *B. smaragdus*, *Distomum rubrum*, *Amaroucium proliferum*, *A. argus*, *Leptoclinum maculatum*, and *Didemnum gelatinosum*, *Botrylloides rubrum*, *B. Leachii*, *B. albicans*; and the polyzoa *Chorizopora Brogniartii*, *Cylindrœcium dilatatum*, *Smittia trispinosa*, *Diastopora suborbicularis*, *Ætea recta*, and *Alcyonidium mamillatum*, which is new to the district.

VI. April 28 to May 1. During two of these days the Committee had the use of the Lancashire sea-fisheries steamer 'John Fell.' On one day dredging was carried on in shallow water along the shore about Fleshwick Bay, to the north of Port Erin; while on the other day advantage was taken of the fine weather to run out to the deep water halfway to Ireland and work inwards. Hauls were taken at the following localities:—

1. Fourteen miles north-west of Port Erin, 70 fathoms, mud: Found *Calocaris Macandreæ*, *Lipobranchius Jeffreysii*, *Rissoa abyssicola*, *Nucula sulcata*, &c.

2. Ten miles north-west of Port Erin, 50 fathoms, mud: Found *Brissopsis lyrifera*, &c.

3. Nine miles west of Contrary Head, 46 fathoms: Found *Cyclostrema millepunctatum*, *Rissoa soluta* and *R. cancellata*, *Eulima bilineata*, &c.

4. Six miles west of Contrary Head, 37 fathoms; *Thyone raphanus, Oscanius membranaceus, Alcyonidium mamillatum, Cellepora dichotoma*, and *Pedicellina gracilis*.

5. Four miles west of Dalby, 25 fathoms; bottom dead shells, &c.: Found *Forbesella tessellata, Stichaster roseus, Palmipes membranaceus, Diphasia pinaster, Eudendrium rameum, Scalpellum vulgare, Pecten maximus* and *P. opercularis* in great abundance.

Pecten maximus yielded to Mr. Thompson the new copepod *Lichomolgus maximus*; while in *P. opercularis* were found the amphipods *Leucothoe articulosa, Tritæta gibbosa*, and *Podocerus Herdmani*.

6. Four miles west of Fleshwick, 20 fathoms: Found *Ophiocoma nigra* in enormous profusion and other common species.

7. One mile off Bradda Head, 15 fathoms: Found *Amphidotus flavescens, Ute glabra, Sertularella rugosa, Coppinia arcta*.

A good deal of shallow water and shore collecting was also done on this occasion, and all the compound ascidians noted under V. were got near Port St. Mary, with the addition of *Glossophorum sabulosum* and *G.* sp. (? n. sp.), both of them new to British seas, the genus only being known up to now from the French coast. A yellow variety of Giard's *Astellium spongiforme* was also obtained.

VII. May 19–22. On one of these days the Committee again had the use of the sea-fisheries steamer 'John Fell.' The weather was rough, and it was only possible to work near the coast to the north of Port Erin, where hauls were taken at the following localities:—

1. South side of Fleshwick Bay, 13 fathoms: *Adamsia palliata* and *Eupagurus Prideauxii, Pleurobranchus plumula, Ascidia virginea*.

2. Opposite Fleshwick beach, 12 fathoms: *Palmipes membranaceus, Solaster papposus, Aporrhais pes-pelicani* (a very large number, all alive), *Lepadogaster bimaculatus*.

3. North side of Fleshwick Bay, 15 fathoms: *Solaster papposus, Plumularia pinnata, Eudendrium capillare, Palmicellaria Skenei* (new to the district), *Scaphander lignarius, Ascidia virginea*.

4. Same line, a little further out: *Palmipes membranaceus, Aporrhais pes-pelicani, Eugyra glutinans*.

5. Across mouth of Port Erin Bay, from near Bradda Head to breakwater, bottom gravel and weeds: *Adamsia palliata, Eupagurus Prideauxii, Ophioglypha albida* (spawning), *Membranipora imbellis, M. Dumerilii, Mucronella ventricosa, M. variolosa, Stomatopora granulata, S. major, Lepralia pertusa, Schizoporella linearis*. Three varieties of the last species were found (1) var. with abortive cells having ovicells, (2) var. with avicularia on the top of blunt umbones, (3) var. approaching *crucifera*, but with a spine on the ovicell.

VIII. June 17–19. The Committee hired the steam trawler 'Lady Loch' for June 18, and having favourable weather were able to work out to the depression between the Isle of Man and Ireland (see chart, Pl. IV., and section). Two or three hauls were taken at each of the following:—

1. Six miles N.W. of Port Erin, 33 fathoms, sandy mud: Found, *Brissopsis lyrifera, Alcyonidium gelatinosum, Porania pulvillus, Adamsia palliata, Palmipes membranaceus, Scalpellum vulgare* on *Antennularia*.

2. Eight miles N.W. of Port Erin, 40 fathoms, mud: Found *Calocaris Macandreæ, Hyalinœcia tubicola*, &c.

3. Eleven miles N.W. of Port Erin, 50 fathoms, mud: *Sagartia*

Herdmani (on *Turritella* shells), *Panthalis Oerstedi*, *Eumenis Jeffreysii*, *Bougainvillea muscus*.

4. Thirteen miles N.W. of Port Erin, 60 fathoms, mud, bottom temperature 48° F., surface temperature 60° F.: Found *Calocaris Macandreæ*, &c.

5. Five miles off Dalby, 30 fathoms, 'reamy' bottom (sand and mud mixed): Sole, turbot, and brill all spawning here. *Lima Loscombii*, *Cerebratulus* (? *angulatus*), *Chætopterus* sp., *Thyone fusus* and *T. raphanus*, *Eurynome aspera*.

6. Four miles off Fleshwick, 23 fathoms: *Pecten opercularis* and *P. maximus* in quantity; *Molgula* sp., *Corella parallelogramma*, *Ascidia plebeia*, *Ascidiella venosa*, *Polycarpa comata*, *Suberites domuncula*.

7. A mile and a half off Bradda Head, 12–15 fathoms: *Styelopsis grossularia*, *Bowerbankia caudata*, *Eurynome aspera*, *Terebella nebulosa*, *Thyone raphanus*.

On all these expeditions, in addition to the animals picked out and preserved at the time, surface and deeper gatherings with the tow-net were taken by Mr. I. C. Thompson; and samples of the bottom and of the 'dredge *débris*' were kept, and these were afterwards carefully examined by Mr. I. C. Thompson for copepoda, by Mr. A. O. Walker for amphipoda and isopoda, by Mr. A. Leicester for small mollusca, and by Dr. Chaster for foraminifera. The sponges collected have been identified by Dr. R. Hanitsch, and several other workers at the Port Erin Biological Station have assisted the Committee with particular sets of animals. The additions to our knowledge of the fauna during the year will now be given, taking the groups in zoological order.

Dr. G. W. Chaster reports that amongst the FORAMINIFERA he has examined two are new to science, and one is a form which seems to require a new genus.

Amongst the SPONGES examined by Dr. R. Hanitsch the following are specially worthy of note: *Ute glabra*, obtained near Port St. Mary (this is practically new to British seas, as it had only been found before at Guernsey); *Esperiopsis* (*Desmacidon*) *fruticosa*, dredged off Calf of Man, 40 to 50 fathoms; *Halichondria* (*Amphilectus?*) *expansa*, off Garwick Head (previously known from Skye); *Suberites* sp. (?), some very large masses, dredged halfway between Isle of Man and Lancashire, 20 fathoms; *Raspailia* sp. (new to the district), dredged off the Calf, 15 fathoms; *Stelletta Collingsi*, from the caves at Spanish Head, Port Erin; *Reniera rosea*, at Fleshwick and Perwick Bay (recorded by Bowerbank from Tenby and Sark only).

We have found in the pools at Port Erin amongst other HYDROIDA the *Lafoea pygmæa* of Alder, and have been able to prove that it is really a *Calycella*; and *Sertularella Gayi* has been added as a new record to the district. In all fifty-seven species of zoophytes have been recorded.

Mr. J. H. Vanstone, curator at the Port Erin Biological Station, has drawn up the following list of the NEMERTIDA collected and identified during the past year, partly by himself and partly by Mr. W. I. Beaumont, Emmanuel College, Cambridge, who was working for some time at the station:—

PROTONEMERTINI: *Carinella annulata*.

MESONEMERTINI: *Cephalothrix bioculata*.

METANEMERTINI: *Amphiporus lactifloreus*, *A. pulcher*, *Tetrastemma dor-*

sale, *T. vermiculatum*, *T. immutabile*, *T. candidum*, *T. Robertianæ*, *T. nigrum*, *T. melanocephalum*, *Nemertes Neesii*.

HETERONEMERTINI: *Lineus longissimus* (=*L. marinus*), *L. obscurus* (=*L. gesserensis*), several varieties; *Cerebratulus* (*angulatus ?*).

In regard to TURBELLARIA, Mr. F. W. Gamble while working at the Port Erin Biological Station last summer drew up a list of the species found in the neighbourhood. This has been published in full in 'Trans. Liverpool Biol. Soc.,' vol. vii. pp. 148–174. The list contains records of twenty-eight species, representing twenty-three genera. Of these the following five species are new to British seas:—*Promesostoma ovoideum*, *P. lenticulatum*, *Byrsophlebs intermedia*, *Plagiostoma sulphureum*, *Oligocladus sanguinolentus*.

The POLYZOA collected on the various expeditions have been examined by Miss L. R. Thornely, who reports that amongst the many forms collected, amounting to about eighty-one species, three at least are new records to the district, viz., *Alcyonidium mamillatum*, *Palmicellaria Skenei*, and *Lepralia edax*.

The COPEPODA obtained both by surface nets and also from the mud and other material from the dredge have yielded Mr. Thompson in all 136 species, of which eighteen are new records to British seas and eleven are new to science. These last are:—*Ameira attenuata*, *Cletodes monensis*, *Herdmania stylifera*, *Cyclops marinus*, *Hersilioides Puffini*, *Jonesiella hyænæ*, *Laophonte spinosa*, *Lichomolgus maximus*, *Monstrilla longicornis*, *Stenhelia denticulata* and *S. hirsuta*. These new species are all described in full, and figured, in Mr. Thompson's 'Revised Report upon the Copepoda of Liverpool Bay,' just published (August 1893) in 'Trans. Liverpool Biol. Soc.,' vol. vii., so it will perhaps be sufficient for the purposes of this report to state the localities at which the new species and those new to British seas were obtained, as follows:—

Labidocera acutum, Dana, off Puffin Island, 10 fathoms, dredged.

Euchæta marina, Prest., in ascidian, Garwick Bay.

Herdmania stylifera, I.C.T., 12 miles west of Port Erin, 39 fathoms, in mud.

Cyclops marinus, I.C.T., 20 miles off Southport, 20 fathoms, dredged.

Giardella Callianassæ, Canu, Liverpool Bay, surface.

Hersilioides Puffini, I.C.T., off Puffin Island, surface.

Stenhelia denticulata, I.C.T., in Port Erin, 5 fathoms, mud.

Stenhelia hirsuta, I.C.T., 12 miles west of Port Erin, 39 fathoms, mud.

Ameira attenuata, I.C.T., in Port Erin, 7 fathoms, mud.

Jonesiella hyænæ, I.C.T., in Port Erin, 5 fathoms, mud.

Laophonte spinosa, I.C.T., in Port Erin, 7 fathoms, mud.

Cletodes monensis, I.C.T., 12 miles west of Port Erin, 39 fathoms, mud.

Monstrilla Danæ, Clap., off Puffin Island and off Port Erin, surface.

Monstrilla longicornis, I.C.T., off Puffin Island, surface.

Monstrilla rigida, I.C.T., off Puffin Island, surface.

Lichomolgus maximus, I.C.T., in *Pecten*, off Port Erin, 20 fathoms.

Sabelliphilus Sarsii, Clap., on *Sabella*, Beaumaris and Puffin Island.

Artotrogus orbicularis, Boeck, Puffin Island, shore.

It will be noticed that one of the above new species has required the formation of a new genus, which Thompson has named *Herdmania*.[1]

[1] *Trans. Liverpool Biol. Soc.*, vol. vii. p. 185.

Besides the above new records many rare species of copepoda have been found, amongst which may be mentioned—

Cyclopicera gracilicauda, Brady, off Puffin Island and off Port Erin.
Bradya typica, Boeck, Port Erin, in mud.
Pseudocalanus armatus, Boeck, Port Erin.
Paracalanus parvus, Claus, Puffin Island.
Labidocera Wollastoni, Lubb., off Puffin Island and open sea.
Misophria pallida, Boeck, off Puffin Island, 10 fathoms.
Cervinia Bradyi, Norm., off Port Erin, 39 fathoms.
Botachus cylindratus, Thor., males (in ascidians), not previously known.
Notopterophorus papilio, Hesse, both males and females (in ascidians).
Robertsonia tenuis, B. & R., off Puffin Island, 10 fathoms.
Paramesochra dubia, Scott, Port Erin, 7 fathoms.
Tetragoniceps Bradyi, Scott, Port Erin, 7 fathoms (with males).
Laophonte horrida, Norm., Port Erin, 4–40 fathoms.
Dactylopus flavus, Claus, off Calf of Man, 20 fathoms.
Lichomolgus agilis, Scott, in cockles.
Cylindropsyllus lævis, Brady, Port Erin, 7 fathoms.
Porcellidium tenuicauda, Claus, off Port Erin, 20 fathoms.
P. viride, Phil., in Port Erin, 4 fathoms.
Thalestris peltata, Boeck, off Little Orme and off Port Erin, 20 fathoms.

The higher crustacea have been examined, and to a large extent collected, by Mr. A. O. Walker, who has supplied the following lists and notes, which record only the more noteworthy additions to the local fauna:—

Schizopoda.

Erythrops elegans, G.O.S., 8 miles off Port Erin, 33 fathoms.
Mysidopsis gibbosa, G.O.S., Port Erin Harbour.
Gastrosaccus sanctus, v. Ben., Port Erin Harbour (the most northerly record of this species).
Haplostylus Normani, G.O.S., Port Erin Harbour (also a southern, Mediterranean, form).

Cumacea.

Diastylis biplicata, G.O.S., 8 miles off Port Erin, 33 fathoms.

Isopoda.

Leptognathia laticaudata, G.O.S., Port Erin Harbour.
Paratanais Batei, G.O.S , from *Pecten maximus* at Port Erin (along with another unidentified species of *Leptognathia*).
Astacilla gracilis, Goods., Port Erin and Rhos Bay.

Amphipoda.

Hyale Nilssonii, Rath., shore, Port St. Mary, Isle of Man.
Perrierella Audouiniana, Bate, from *Pecten maximus*, at Port Erin.
Hoplonyx similis, G.O.S., Laxey Bay, Isle of Man.
Harpinia crenulata, Boeck, 8 miles off Port Erin, 39 fathoms.

Amphilochus melanops, n. sp., off Little Orme (see below).

Metopa borealis, G.O.S., Colwyn Bay and Menai Strait, 2½ fathoms.

Metopa pusilla, G.O.S., Colwyn Bay, 2½ fathoms.

Metopa Bruzelii, Goës, off Little Orme, 5–10 fathoms.

Leucothoe spinicarpa, Abild., from *Ascidia mentula* off Clay Head, and from *Pecten* off Port Erin.

Synchelidium brevicarpum, Bate, Port Erin Harbour.

Paramphithoe monocuspis, G.O.S., off Puffin Island, &c. (probably immature form of *P. bicuspis*).

Paramphithoe assimilis, G.O.S., Puffin Island, &c.

Stenopleustes Malmgreni, Boeck, Rhos Bay, 4 fathoms (not previously known out of Norwegian waters).

Liljeborgia Kinahani, Bate, 3 miles west of Calf, 19 fathoms.

Melphidippa macra, Norm., 8 miles west of Port Erin, 33 fathoms. (These show the perfect antennæ which were wanting in Dr. Norman's Shetland specimens.[1])

Maera longimana, Thomp., 3 miles off Port Erin, 20 fathoms.

Cheirocratus assimilis, Lillj., Port Erin Harbour.

Photis Reinhardi, Kröy., off Little Orme.

Megamphopus cornutus, Norm., 8 miles west of Port Erin, 33 fathoms, and off Little Orme 5–10 fathoms. A comparison of specimens of this from Norway, Shetland, Cumbrae, and Isle of Man shows that the horn on the first epimere diminishes and disappears as the species goes south.

Podocerus Herdmani, n. sp., off Port Erin, 20–35 fathoms, and Laxey Bay (for diagnosis and figure see pp. 528 and 529).

Podocerus isopus, A.O.W , Rhos Bay, low water, abundant.

Ericthonius difformis, M. Edw., Laxey Bay, 10 fathoms (colony of tubes attached to *Zostera*).

Siphonœcetes Colletti, Boeck, Port Erin Harbour, off Garwick Head, and off Little Orme, 5–10 fathoms. Seven of these Amphipoda, *Harpinia crenulata*, *Amphilochus melanops*, *Metopa Bruzelii*, *Metopa pusilla*, *Paramphithoe monocuspis*, *Podocerus Herdmani*, and *Siphonœcetes Colletti*, have not been previously recorded in British seas.

In regard to the new species, *Amphilochus melanops*, Mr. Walker states :—

'This species is interesting from being very closely allied to *A. Marionis*, Stebb., from Marion Island, from which it differs chiefly in its larger eyes, and in having the palm and hind margin of both gnathopods less convex. From *A. oculatus* (Hansen), from the west coast of Greenland, which it resembles in the eye, it differs in having no spiniform process to the anterior margin of the hand of the second gnathopod; and from *A. tenuimanus* (Boeck) it differs in the eye, which is described by Sars as being small, imperfectly developed, and light red; in the telson, which is much shorter, and in the armature of the outer plates of the maxillipedes, which are terminated by a single spine, exactly as in *A. Marionis*, instead of two spines, as drawn by Sars. The mandibles have the molar tubercle intermediate in character between *Amphilochus* and *Gitanopsis* (Sars), to whose *Gitanopsis inermis* this species also has a great resemblance, but differs in the above character and in the length of the telson, which closely resembles that of *A. Marionis*. The length of a female with ova is 2 mm.

'The occurrence of species so closely allied as those mentioned above in

[1] *British Association Report*, 1868, p. 280.

such widely separated regions as Marion Island in latitude 48° S. and the west coast of Greenland is very interesting, as also is the presence of well-developed eyes in *A. melanops* and *A. oculatus*, taken in from 5 to 25 fathoms; while in *A. Marionis* and *A. tenuimanus*, taken in 100–200 fathoms, they are imperfect. It is very probable that it was this species (*A. melanops*) to which Mr. Stebbing referred[1] as having been sent to him by Mr. Robertson from the Clyde.'

In regard to the mollusca a large number of species have been collected by the Committee; and Mr. Alfred Leicester, of Liverpool, who has examined and identified them, has drawn up a list of sixty-one species which have not before been found off the south coast of the Isle of Man, while the following twelve—*Kellia suborbicularis*, *Eulima intermedia*, *Odostomia Lukisi*, *O. conoidea*, *Rissoa abyssicola*, *R. violacea*, *Cylichna umbilicata*, *Philine scabra*, *Bulla utriculus*, *Melampus myosotis*, *Trochus helicinus*, and *Cyclostrema millepunctatum*—are new records to the district.

We have also taken the two brachiopods *Crania anomala* and *Terebratula caput-serpentis*, and the rare cephalopod *Sepiola scandica* (new record), as well as the more common *S. atlantica*.

In regard to fishes, although most of the hauls on the expeditions, having been taken with the naturalists' dredge, were not suitable for the capture of fish, still the Committee, chiefly through the exertions of Mr. P. F. J. Corbin, of the Fisheries Laboratory, University College, Liverpool, have collected records of 114 species of fish found in the district, and have added the following species, previously unknown: *Solea variegata*, *Gobius quadrimaculatus*, and *Argentina sphyræna*.

In conclusion it may be stated that the Committee have conducted eight expeditions between September and June, and have explored a considerable amount of the Irish Sea around the Isle of Man, and especially to the south and west. They have collected and identified about a thousand species of marine animals, of which thirty-eight are new records to the British fauna, 224 are new to the particular district (this part of the Irish Sea), and seventeen are new to science.

The Committee give with this report a chart (Plate IV.) showing the area under investigation, with the zones of depths indicated, and a section from Ireland to Lancashire, through the Isle of Man, showing the marked difference in depth between the sea to the east and that to the west. They are also preparing a larger and more detailed chart of the sea to the west and south of the Isle of Man, where most of their dredging has been carried on, in which the nature of the bottom and other particulars will be given; but they wish to make this chart more complete by the incorporation of further observations before publishing. As the Committee are now applying to be reappointed, with a further grant to enable them to carry on the work for at least another year, they hope that the more detailed chart will appear in illustration of a second report at the next meeting of the Association.

[1] '*Challenger*' *Report on Amphipoda*, p. 746.

Occupation of a Table at the Zoological Station at Naples.—Report of the Committee, consisting of Dr. P. L. Sclater, Professor E. Ray Lankester, Professor J. Cossar Ewart, Professor M. Foster, Mr. A. Sedgwick, Professor A. M. Marshall, *and* Mr. Percy Sladen (*Secretary*).

I. *On the Action of Coloured Light on Assimilation.* *By* Cecil C. Duncan.
II. *On the Function and Correlation of the Pallial Organs of the Opisthobranchiata.* *By* John D. F. Gilchrist.

The table at the Naples Zoological Station hired by the British Association has been occupied during the past year, under the sanction of your Committee, by Mr. Cecil C. Duncan and Mr. John D. F. Gilchrist. The object of Mr. Duncan's research was to investigate the action of coloured light on assimilation in marine algæ, and that of Mr. Gilchrist's the function and correlation of the pallial organs of the Opisthobranchiata. The reports furnished by both these gentlemen are appended, and give evidence of much patient work satisfactorily carried out.

The Committee have received two applications for permission to use the table during the ensuing year. The first is from Mr. E. S. Moore, who proposes to investigate the origin of the reproductive elements in various types of fishes, as well as in other marine organisms; and the second is from Mr. Edgar J. Allen, who wishes to continue his researches on the development of the decapod crustacea. Each of these applications is for a period of six months, the first to commence at the end of September and the second in April. The occupation of the table for the entire year is thus provided for. Both these gentlemen have already made valuable contributions to our knowledge of the subjects upon which they are engaged, and important results are likely to be obtained from the investigations they propose to carry on at Naples.

Your Committee trust that the Association will sanction the payment of the grant of 100*l.*, as in previous years, for the hire of the table in the Zoological Station at Naples.

Notwithstanding the number of marine zoological stations which have sprung into existence in different parts of the world during the past decade, the Naples Zoological Station steadily continues to extend both in scope and in popularity, and each year shows an increase in the number of naturalists who study in its laboratories: 747 workers have occupied tables from the opening of the Station up to the end of June 1893, 71 names being enumerated on the list for last year.

The Physiological Laboratory, which was built in 1890–91, and forms a handsome addition to the original building, is now thoroughly equipped, and is in full working order. A number of important investigations have been conducted in this department of the Station during the past year, and doubtless many workers in the wide field of physiology will now be attracted to Naples to avail themselves of the exceptional facilities there offered for carrying out such researches.

The Chemical Laboratory is also a distinct and much appreciated gain to the institution.

The Library, which has always been felt to be an adjunct of incalculable importance to the study and convenience of all who have worked at the Station, is increasing so rapidly that new and more commodious

rooms are now being prepared, capable of accommodating double or treble the present number of books. The Director is unrelenting in his exertions to make the Library as complete as possible, and it is his aim that it should one day rank as the most complete Zoological Library in existence.

The progress of the various publications undertaken by the Station is summarised as follows :—

1. Of the 'Fauna und Flora des Golfes von Neapel' the monograph by Dr. Giesbrecht on 'Pelagic Copepoda' (831 pp., 54 plates) has been published ; and two other equally large monographs by Professor Della Valle on 'Gammarini' (about 950 pp. and 60 plates) and by Professor Spengel on 'Balanoglossus' (about 800 pp. and 30 plates) will appear before the end of the year. Monographs by Dr. W. Müller on 'Ostracoda' and by Dr. Jatta on 'Cephalopoda' are ready, and the printing of the former has been commenced. Monographs are being prepared by Dr. Bürger on 'Nemertinea,' by Professor Apáthy on 'Hirudinea,' by Professor Ludwig on 'Echinodermata,' and by Dr. Scheviakoff on 'Foraminifera' ; and a botanical monograph by Professor Falkenberg on 'Rhodomeleæ' is nearly ready.

2. Of the 'Mittheilungen aus der Zoologischen Station zu Neapel,' vol. x., parts iii. and iv., with 18 plates, have been published; and vol. xi., parts i. and ii., with 13 plates, are in the press.

3. Of the 'Zoologischer Jahresbericht' the whole 'Bericht' for 1892 has been published.

The details extracted from the general report of the Zoological Station, which have been courteously furnished by the officers, will be found at the end of this report. They embrace lists (1) of the naturalists who have occupied tables since the last report ; (2) of the works published during 1892 by naturalists who have worked at the Zoological Station. A list of the specimens sent out by the Station during the past year has also been furnished.

I. *Report on the Occupation of the Table.* *By* Mr. Cecil C. Duncan.

The algæ to be experimented upon were kept in a large tank, with a good stream of water running through, until they had the appearance of being quite healthy. The determination of the composition of the gas given off from the different coloured algæ, when subjected to the action of different coloured light, was then proceeded with. The coloured solutions, &c., are as follows :—Diffused daylight; red glass which passed only rays from about B of the solar spectrum to midway between C and D; yellow light from a saturated solution of bichromate of potash which passed rays from B to about midway between D and E; violet glass passing all the blue and violet and a little red and yellow light; violet light from a strong solution of ammonio-cupric sulphate which absorbed all light up to E, and finally a dilute alcoholic solution of chlorophyll from grass. The gas analyses were made in the gas-room attached to the chemical laboratory, according to Bunsen's method, the CO_2 being determined by absorption with NaOH and the O_2 by explosion with hydrogen. The N_2 was determined by difference. The same portion of the plant was experimented on with the coloured solutions, &c., mentioned above. Diffused daylight produced the maximum quantity of O_2, and only in four out of seventeen cases did coloured light produce more, viz.—

—	Diffused Light. O_2 %	Red Glass. O_2 %	Yellow Light. O_2 %	Ammonio-cupric Sulphate. O_2 %
I. *Haliseris polypodioides* .	48·635	40·326	47·514	50·021
II. *Sebdenia dichotoma* . .	28·070	30·416	20·994	26·211
III. *Chrysymenia uvaria* .	29·423	28·231	29·610	10·468
IV. *Peyssonelia squamaria* .	35·200	30·114	35·720	20·111

From thirteen experiments with red and yellow light only two experiments with the red produced more O_2 than the yellow, viz.—

—	Red Light. O_2 %	Yellow Light. O_2 %
I. *Haliseris polypodioides* . . .	50·864	49·103
II. *Sebdenia dichotoma*	30·416	20·994

Diffused light, red and yellow light, all gave larger quantities of O_2 than the violet glass. From seven experiments with the ammonio-cupric sulphate solution *Sebdenia* was the only one to give a larger quantity of O_2 than produced from the action of yellow light.

—	Diffused Light. O_2 %	Red. O_2 %	Yellow. O_2 %	Violet. O_2 %
S. dichotoma	28·07	30·416	20·994	26·211

Sebdenia, after being exposed to violet light, lost its original colour, and turned a pale green. Several algæ, after having been exposed to the violet light, were killed. The other colours did not destroy so rapidly.

From the green light of the chlorophyll solution the quantity of O_2 found was very small; in one case the total quantity of gas given off was only 0·268 c.c. at 0° C., and 760 mm. mercury.

—	Diffused Light. O_2 %	Chlorophyll Solution. O_2 %
Codium tomentosum	58·657	7·210
Plocamium coccineum	32·56	3·098

The next series of experiments were made in order to determine the exact quantity of O_2 given off from the same plant under different rays of light. A small quantity of the dissolved gases was removed from the sea water by means of a pump. A portion of the plant to be experimented on was placed in an air-tight flask with some of this water. The O_2 was determined before and after the experiment by Winkler's method, the difference being the O_2 given off by the plant under experiment. The results varied considerably, the principal cause being due, I think, to the unhealthy state of some of the algæ. After some care the results obtained agreed fairly well with those obtained by the first series of

experiments, *Sebdenia*, *Codium*, and also *Haliseris* giving results very similar to those in the first series of experiments.

On examining the absorption spectrum of the seventeen species of algæ, one is struck by the constant absorption of the extreme red almost up to B, and the strong absorption between B and C which is so characteristic of green chlorophyll. The rays absorbed between B and C are stated by several observers to be the rays most necessary for aiding assimilation. Alcoholic solutions of green and olive algæ had a red fluorescence similar to that exhibited by solutions of green chlorophyll, and if the spectrum from a small spectroscope is projected on to the surface of the solutions of the colouring matter of olive or green algæ, the liquid fluoresces of a dark red colour from about B to some distance in the violet, the red fluorescence being brightest where the greatest absorption takes place in the original alcoholic solution. No fluorescence could be detected in the living plant.[1] A few preliminary experiments were made in order to determine the *quality* of the light penetrating into the sea, but nothing worth mentioning was observed. I hope to continue these experiments with properly made apparatus.

To the staff of the Station my sincere thanks are due for the great kindness and assistance I have received at their hands.

II. *Report on the Occupation of the Table.* *By* Mr. John D. F. Gilchrist.

I beg to submit a report of the work done during my occupation of the table of the British Association at the Zoological Station in Naples.

I had for six months been working in the Laboratory of Professor Arnold Lang, on the subject of the pallial organs of the Opisthobranchiata. In order to understand the function and correlation of these different organs, as well as to make use of recent methods of silver and methylen-blue staining and of dissociation, it was necessary to have the animals in the living condition. Accordingly I gladly availed myself of the permission of the British Association to occupy the table at Naples, where alone I could get the necessary abundance and variety of material for such a comparative study. I applied for three months, to begin on April 10; but finding such abundance of material and opportunities for work, I applied for another month, and this was granted.

With the material procured I am fully satisfied. Not only were such forms as *Aplysia*, *Bulla*, and *Pleurobranchæa* to be had in more than abundance, but others, such as *Notarchus*, *Aeera*, &c., were plentiful, and other forms which were not procured during my stay, such as *Pleurophyllidea* and *Lobiger*, were kindly given me from the stock of preserved material. These, along with the many Nudibranchiata which turned up, put at my disposal abundance of material for a comparative study.

My first endeavour was to thoroughly understand the functional mechanism of the pallial complex, which presents such a variety of

[1] The band present between C and D in an alcoholic solution of chlorophyll was only to be found in a species of *Phyllophora*. The very faint band at the junction of the yellow and green in an alcoholic solution of chlorophyll was found in six out of seventeen species, viz., *Sebdenia*, *Vidalia*, *Peyssonelia*, *Plocamium*, and *Ceramium*, and very dark in *Halymenia*. A broad dark absorption band is very constant between *b* and F, and in only seven species could the violet be said to be absorbed strongly.

interesting modifications in the Opisthobranchiata. This I did by observations on the living animal. Thus, for instance, the mantle of *Aplysia* was found sometimes to exhibit a motion the effect of which was to keep the water in circulation round the gills. Again, a remarkable process of flaccid skin at the front end of the mantle was found to play an important part in conjugation. I found it also very instructive to ascertain the strength and direction of the current of water in the pallial cavity and elsewhere. Thus in *Aplysia depilans* and *A. punctata* the current was much feebler than might have been expected, and in *Aplysia limacina* it was even more so, while in other forms there was none at all. These and similar facts were noted throughout a variety of forms, and enabled me to deduce some general conclusions—for instance, that the development of the osphradium is in intimate relation with the presence and strength of the current of water, *e.g.*, that in *Aplysia depilans*, where there is a distinct current, the osphradium is more highly developed than in *Aplysia limacina*, where the current is markedly less, and that where, as in *Pleurobranchœa* or *Umbrella*, there is no current of water passing over the gills, but is drawn directly into them, there is no sign of an osphradium. Again, where, as in *Pleurobranchus*, the current first passes over the rhinophora, there is no osphradium. This is more markedly the case in the Nudibranchiata, where the place most exposed to the influence of water was found to be the rhinophora. By facts of this nature, and also by a comparison with the Prosobranchiata, as far as my time would allow, I was confirmed in my belief that there exists a relation of direct proportion between the current of water and the development of the osphradium, there exists a relation of indirect proportion between Osphradium and Rhinophora, and that the Osphradium, whose function has hitherto been regarded as obscure, is to be explained as an ordinary olfactory organ in the same sense as the rhinophora are olfactory organs. To further confirm this I made a series of experiments, but although these seemed to be confirmatory they were not decisive. This difficult physiological work has still to be much further developed.

By direct observation of the living animal I was able to note the details of the contraction of the gills by which the blood is propelled; also to find some renal openings difficult to discover in preserved material. I found also in the remarkable gland before the gills in *Pleurobranchœa* that there existed a current of water passing over the orifice and down under the gills; also that there was no excretion of mucus on irritation. I was thereby enabled to draw some conclusions as to its function. I found these and similar facts as instructive as the anatomical details I had previously ascertained.

With Golgi's methods I had no more success than others who have tried them on the same animals.

With the methylen-blue method of staining living nerve fibres I at first had also little success, but ultimately succeeded in getting a good colouring by laying the nervous system bare and leaving it for about twelve hours in a weak solution ($\frac{1}{2000}$ per cent.). Among other things I was enabled by this means to convince myself that no direct connection by means of nerve fibres exists between osphradium and cerebral ganglia, as has been found to be the case in lamellibranchs, though sections cut and coloured in the usual way present an appearance which might be mistaken for this.

I had considerable trouble in finding a suitable fluid for dissociation,

but at last found that picric acid ammoniac controlled by picrocarmine was very suitable for the tissue. The picrocarmine having a slightly fixing effect could be used in larger or smaller proportions, according to the nature of the tissue. It at the same time afforded a good muscular stain. For cilia I found that a few minutes' exposure to vapour of osmic acid before dissociation gave good results. By these means I was able to isolate cells of neural epithelium gills and glands, &c.

Though some of the results of my work here have been negative rather than positive I have reason to be satisfied, more especially with the physiological facts ascertained. The material I have collected will be used for the working out of further anatomical details, and the whole will form the subject of a future publication.

Not among the least of the advantages which my stay at the Station has afforded me was the opportunity of making the personal acquaintance of other naturalists working in the same territory. I found our interchange of ideas and criticism invaluable.

I have to express my gratitude to the British Association for the opportunity, which I could not otherwise have had, of completing my work and making it more than a mere collection of anatomical details. My thanks are also due to the authorities at the Station for their unexceptionable kindness.

III. *A List of Naturalists who have worked at the Zoological Station from the end of June* 1892 *to the end of June* 1893.

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
678	Prof. W. Einthoven .	Holland . . .	July 1, 1892	Sept. 7, 1892
679	Prof. W. F. R. Weldon	Cambridge . .	„ 10, „	„ 21, „
680	Miss Tebb . .	„	„ 10, „	„ 21, „
681	Prof. A. Della Valle .	Italy	„ 12, „	Oct. 6, „
682	Dr. G. Rolando .	„	„ 14, „	Sept. 5, „
683	Dr. F. S. Monticelli .	„	Aug. 1, „	Oct. 16, „
684	Dr. G. Mazzarelli .	„	„ 1, „	—
685	Dr. G. d'Abbundo .	„	„ 1, „	Oct. 8, „
686	Prof. S. Trinchese .	„	„ 8, „	—
687	Stud. V. Diamare .	„	„ 15, „	—
688	Prof. Polejaeff . .	Russia	„ 17, „	Sept. 23, „
689	Mr. C. Duncan . .	British Association .	„ 22, „	Oct. 30, „
690	Prof. K. von Kostanecki	Hesse	Sept. 1, „	Sept. 17, „
691	Dr. F. Röhmann .	Prussia	„ 2, „	Oct. 10, „
692	Dr. C. Crety . .	Italy	„ 6, „	Nov. 29, „
693	Prof. H. Virchow .	Prussia	„ 6, „	Oct. 27, „
694	Dr. D. Popoff . .	Russia	„ 6, „	„ 27, „
695	Dr. H. Driesch . .	Hamburg . .	„ 20, „	May 2, 1893
696	Dr. C. Herbst . .	Academy, Berlin .	„ 20, „	„ 2, „
697	Prof. J. V. Carus .	Saxony . . .	„ 23, „	Oct. 10, 1892
698	Dr. C. St. Hilaire .	Russia	„ 29, „	Nov. 6, „
699	Dr. G. W. Field .	Amer. 'Davis' Table	Oct. 5, „	Mar. 29, 1893
700	Dr. G. W. Müller .	Prussia	„ 18, „	„ 27, „
701	Dr. P. Hauptfleisch .	„	„ 25, „	Apr. 14, „
702	Prof. N. Kastschenko	Russia	Nov. 8, „	Mar. 7, „
703	Prof. N. Wagner .	„	„ 8, „	Apr. 22, „
704	Dr. W. Kruse . .	Zoological Station .	„ 9, „	Dec. 9, 1892
705	Dr. P. Pasquale .	„ „ .	„ 9, „	„ 9, „

III. A LIST OF NATURALISTS—*continued.*

Number on List	Naturalist's Name	State or Institution whose Table was made use of	Duration of Occupancy	
			Arrival	Departure
706	Dr. A. von Bunge	Russia (Navy)	Nov. 15, 1892	Apr. 18, 1893
707	Dr. B. Baculo	Italy	Dec. 6, „	—
708	Prof. N. Polejaeff	Russia	„ 17, „	—
709	Prof. F. S Monticelli	Italy	„ 24, „	—
710	Dr. G. Jatta	„	Jan. 1, 1893	—
711	Dr. L. Zoja	„	„ 3, „	Mar. 3, „
712	Dr. E. Veit	Prussia	„ 16, „	„ 24, „
713	Dr. J. H. Vernhout	Holland	„ 17, „	June 11, „
714	Prof. A. Froriep	Würtemberg	„ 20, „	Apr. 15, „
715	Dr. F. Stuhlmann	Hamburg	„ 25, „	Mar. 9, „
716	Dr. R. Burckhardt	Prussia	Feb. 2, „	„ 27, „
717	Dr. V. Willem	Belgium	„ 5, „	—
718	Dr. Sänger	Bavaria	„ 10, „	Apr. 5, „
719	Sr. B. Cañizares	Spain	„ 18, „	„ 18, „
720	Dr. A. Köhler	Hesse	„ 18, „	May 29, „
721	Dr. G. Cano	Italy	Mar. 3, „	—
722	Dr. G. Andersson	Zoological Station	„ 6, „	Mar. 22, „
723	Mr. H. Bury	Cambridge	„ 6, „	Apr. 30, „
724	Dr. R. von Erlanger	Baden	„ 7, „	May 29, „
725	Dr. J. von Uexküll	„	„ 7, „	„ 27, „
726	Dr. C. Kohl	Saxony	„ 8, „	—
727	Stud. T. List	Hesse	„ 8, „	May 21, „
728	Dr. O. Lanz	Switzerland	„ 8, „	„ 10, „
729	Dr. T. Beer	„	„ 8, „	June 23, „
730	Prof. Count Solms-Laubach	Strasburg	„ 8, „	Apr. 14, „
731	Dr. G. H. Parker	Amer. 'Davis' Table	„ 10, „	June 1, „
732	Dr. P. Klemm	Saxony	„ 10, „	Apr. 27, „
733	Dr. R. Hesse	Würtemberg	„ 13, „	May 5, „
734	Miss S. Perejaslawzewa	Russia	„ 17, „	—
735	Dr. J. Schaffer	Austria	„ 18, „	Apr. 15, „
736	Prof. C. Keller	Switzerland	„ 18, „	„ 10, „
737	Prof. J. Rückert	Bavaria	„ 20, „	„ 14, „
738	Prof. K. von Kostanecki	Austria	„ 20, „	May 1, „
739	Dr. E. Lindemann	Prussia	„ 20, „	Mar. 29, „
740	Prof. P. Knoll	Austria	„ 27, „	Apr. 30, „
741	Mr. R. T. Günther	Oxford	Apr. 1, „	—
742	Mr. J. D. F. Gilchrist	British Association	„ 11, „	—
743	Dr. C. Zelinka	Austria	„ 15, „	Mar. 15, „
744	Dr. de Meyere	Holland	May 4, „	—
745	Dr. G. John	Saxony	„ 25, „	—
746	Ten. Juan Bascon	Spain	„ 26, „	—
747	Prof. F. Legge	Italy	June 27, „	—

IV. *A List of Papers which have been published in the year* 1892 *by the Naturalists who have occupied Tables at the Zoological Station.*

Dr. C. Hartlaub . . Zur Kenntniss der Anthomedusen. 'Nachr. K. Ges. Wiss.,' Göttingen, 1892.

E. A. Minchin . . Notes on a sieve-like membrane across the oscula of a species of Leucosolenia, with some observations on the histology of the Sponge. 'Quart. Journ. Micr. Science,' vol. 33, 1892.

E. A. Minchin . .	Some points in the Histology of Leucosolenia (Ascetta) clathrus, O.S. 'Zool. Anzeiger,' 1892.
" " . .	The oscula and anatomy of Leucosolenia clathrus, O.S. 'Quart. Journ. Micr. Science,' vol. 33, 1892.
Dr. G. Maurea . .	Ueber eine bewegliche Sarcine. 'Centralbl. f. Bacteriologie u. Parasitenkunde,' Bd. 4, 1892.
Prof. J. Rückert . .	Zur Entw.-Geschichte des Ovarialeies bei Selachiern. 'Anat. Anz.,' 1892.
Dr. E. Ballowitz . .	Ueber den feineren Bau der Muskelsubstanzen. 1. Die Muskelfaser der Cephalopoden. 'Arch. f. Mikr. Anat.,' Bd. 39, 1892.
Dr. G. Cano . . .	Sviluppo dei Portunidi. Morfologia dei Portunidi e Corystoidei. 'Soc. Ital. delle Scienzi,' T. 8, 1892.
" . . .	Sviluppo postembrionale dello Stenopus spinosus. 'Boll. Soc. Nat. Napoli,' V. 5, 1892.
Dr. O. Bürger. . .	Zur Systematik der Nemertinenfauna des Golfes von Neapel, vorläufige Mitthlg. 'Nach. K. Ges. Wiss.,' Göttingen, 1892.
Prof. A. Kowalewsky .	Einige Beiträge zur Bildung des Mantels der Ascidien. 'Mém. Acad. Imp. Sciences,' St.-Pétersbourg, vol. 38, 1892.
" " . .	Ein Beitrag zur Kenntniss der Excretionsorgane der Pantopoden. *Ibid.*
Dr. A. Russo . . .	Embriologia dell' Amphiura squamata, Sars., Morfologia dell' apparecchio riproduttore. 'Atti R. Accad. Sc. Fis. e Mat.,' vol. 5, 1892.
" . . .	Contribuzione all' Embriologia degli Echinodermi e sviluppo dell' Asterias glacialis. 'Boll. Soc. Nat. Napoli,' vol. 6, 1892.
" . . .	Della Embriologia e dell' apparato riproduttore dell' Amphiura squamata. *Ibid.*, vol. 5.
H. Russel . .	Impfungsversuche mit Giards pathogenem Leuchtbacillus. 'Centralbl. f. Bacteriologie u. Parasitenkunde,' Bd. 11, 1892.
J. B. Platt . . .	Fibres connecting the nervous system and chorda in Amphioxus. 'Anat. Anz.,' 1892.
Dr. O. Maass . . .	Ueber Bau u. Entwickelung der Cuninenknospen. 'Zool. Jahrbücher,' Abth. 'Anatomie u. Ontogenie,' Bd. 5, 1892.
" . . .	Die Metamorphose von Esperia Lorenzi O.S., nebst Beobachtungen an anderen Schwammlarven. 'Mitth. Zool. Station, Neapel,' Bd. 10, 1892.
E. W. MacBride . .	The development of the genital organs, pseudo-heart (ovoid gland), axial and aboral sinuses in Amphiura squamata. 'Zool. Anz.,' 1892, and 'Quart. Journ. Micr. Science,' vol. 34, 1892.
Prof. G. von Koch . .	Kleinere Mittheilungen über Anthozoen. 7. Ueber Kolonien von Bebryce mollis Phil., welche Cornulariden ähnlich sind. 'Morph. Jahrbuch,' Bd. 18, 1892.
Dr. F. Raffaele . .	Ricerche sullo sviluppo del sistema vascolare nei Selacei. 'Mitth. Zool. Station, Neapel,' Bd. 10, 1892.
Dr. R. von Erlanger .	On the paired nephridia of Prosobranchs, the homologies of the only remaining nephridium of most prosobranchs, and the relations to the gonad and genital duct. 'Quart. Journ. Micr. Science,' vol. 33, 1892.
" " .	Mittheilungen über Bau u. Entwickelung einiger marinen Prosobranchier. 'Zool. Anz.,' 1892.
Prof. M. von Lenhossék .	Beobachtungen an den Spinalganglien u. dem Rückenmark von Pristiurusembryonen. 'Anat. Anz.,' 1892.
Dr. J. von Uexküll .	Physiologische Untersuchungen an Eledone moschata. 'Zeitschr. f. Biologie,' 1892.
G. Bidder . . .	Note on Excretion in Sponges. 'Proc. Royal Society,' v. 51, 1892.
A. Willey . . .	Observations on the postembryonic development of Ciona intestinalis and Clavellina lepadiformis. *Ibid.*

A. Willey . . .	On the development of the hypophysis in the Ascidians. 'Zool. Anz.,' 1892.
Dr. H. Driesch . .	Entwickelungsmechanismus. 'Anat. Anz.,' 1892.
" . .	Entwickelungsmechanische Studien, III.–VI. 'Zeitschr. f. wiss. Zoologie,' B. 55, 1892.
Dr. S. Kaestner . .	Ueber die allgemeine Entwickelung der Rumpf- u. Schwanzmuskulatur bei Wirbelthieren, &c. 'Arch. f. Anat. u. Physiol.,' Anat. Abth., 1892.
Dr. B. Rawitz . . .	Der Mantelrand der Acephalen, 3. Theil. 'Jen. Zeitschr. f. Naturw.,' 1892.
Dr. J. Hjort . . .	Zum Entwickelungscyclus der zusammengesetzten Ascidien. 'Zool. Anz.,' 1892.
Dr. W. Nagel . . .	Der Geschmackssinn der Actinien. *Ibid.*
" . . .	Fortgesetzte Beobachtungen über galvanische Reizung bei Wasserthieren. 'Archiv f. Physiol. Pflüger,' 1892.
" . . .	Bemerkungen über auffallend starke Einwirkung gewisser Substanzen auf die Empfindungsorgane einiger Thiere. 'Biol. Centralblatt,' 1892.
Dr. F. Schütt . . .	Ueber Organisationsverhältnisse des Plasmaleibes der Peridineen. 'Sitz.-Ber. K. Preuss. Akad. Wiss.,' Berlin, 1892.
Dr. G. Mazzarelli . .	Intorno al preseso occhio anale delle larve degli Opistobranchi. 'Rendic. K. Acc. Lincei,' 1892.
" . .	Sullo sviluppo postlarvale della conchiglia dei Tectibranchi. 'Boll. Soc. Nat. Napoli,' 1892.
" . .	Note anatomiche sulle Aplysiidæ. *Ibid.*
" . .	Ricerche anatomiche sul Lobiger Serradifalii. *Ibid.*
Th. T. Groom . . .	On the early development of Cirripedia. 'Proc. Royal Soc.,' vol. 52, 1892.
Dr. G. Antipa . .	Ueber die Beziehungen der Thymus zu den sog. Kiemenspaltenorganen bei Selachiern. 'Anat. Anz.,' 1892.
Prof. E. B. Wilson . .	The Cell Lineage of Nereis, a contribution to the cytogeny of the Annelid body. 'Journ. of Morphol.,' 1892.
Dr. B. Lwoff . . .	Ueber einige wichtige Puncte in der Entwickelung des Amphioxus. 'Biol. Centralbl.,' 1892.
Dr. F. S. Monticelli .	Notizia preliminare intorno ad alcuni inquilini degli Holothurioidea del Golfo di Napoli. 'Monitore Zoologico,' 1892.
" .	Di alcuni organi di tatto nei Tristomidi, &c. 'Boll. Soc. Nat. Napoli,' 1892.
" .	Della spermatogeneri nei Trematodi. *Ibid.*
" .	Notizie di alcune specie di Taenia. *Ibid.*
" .	Sul nucleo vitellino delle uova dei Trematodi. *Ibid.*
" .	Studii sui Trematodi endoparassiti. Sul genere Notocotyle. *Ibid.*
Dr. A. Kriedl . . .	Weitere Beiträge zur Physiologie des Ohrlabyrinthes, 'Sitz.-Ber. K. Akad. Wiss. Wien.,' M.N.W. Classe, 1892.
Prof. W. Salensky . .	Ueber die Thätigkeit der Kalymmocyten (Testazellen). 'Festschrift,' R. Leuckart, Leipzig, 1892.
Dr. C. Herbst . . .	Experimentelle Untersuchungen über den Einfluss der veränderten chemischen Zusammensetzung des umgebenden Mediums auf die Entwickelung der Thiere. I. Theil, Versuche an Seeigeln. 'Zeitschr. f. wiss. Zoologie,' Bd. 55, 1892.
Dr. M. Cazurro . .	Anemonia sulcata Pennant, Estudio Anatómico-histológico de una Actinia. 'Anal. de la Soc. Esp. de Hist. Nat.,' T. 21, 1892.

Investigations made at the Laboratory of the Marine Biological Association at Plymouth.—Report of the Committee, consisting of Professor E. RAY LANKESTER (*Chairman*), Professor M. FOSTER, Professor S. H. VINES, *and* Mr. S. F. HARMER (*Secretary*).

I. *The Turbellaria of Plymouth Sound. By* F. W. GAMBLE, *B.Sc.*
II. *The Larvæ of Decapod Crustacea. By* EDGAR J. ALLEN, *B.Sc.*
III. *Notes on How Fish find Food. By* GREGG WILSON, *M.A., B.Sc.*

THE object specially mentioned by the terms of the grant of 30*l.* placed at the disposal of the Committee for the present year has been attained by reappointing Mr. Gamble to the use of a table to enable him to extend his observations on British Turbellaria. Mr. Allen has been reappointed to allow him to continue his researches on the development of Decapod Crustacea; and Miss F. Buchanan, whose observations made in 1891 as the result of a previous appointment by the Committee are recorded in the Report for 1892 (p. 356), has been reappointed with the intention of studying the development of *Magelona*.

The Committee have thus appointed—

Mr. F. W. Gamble B.Sc., Owens College, Manchester, for one month, from August 8, 1893.
Mr. Edgar J. Allen, B.Sc., University College, London, for two months, from June 1, 1893.
Miss F. Buchanan, B.Sc., University College, London, for one month, from September 1, 1893.

The Committee have thus expended 15*l.* (taking into account the month which belongs to the Association free of charge), leaving an unexpended balance of 15*l.*, which they trust will be placed at their disposal to allow them to carry on their work next year.

They are naturally unable to furnish any account of results arrived at during the present year, but they are happy to be in a position to present the following reports on the work of the preceding year. These reports, taken in conjunction with the others which have been published in previous years, will serve to show that important results have been arrived at with the assistance of the grants made to this Committee.

I. *Report on the Occupation of the Table.*
The Turbellaria of Plymouth Sound. By Mr. F. W. GAMBLE, *B.Sc.*

During August and September of 1892 I occupied the Association's table, and was thus enabled to investigate the Turbellaria of Plymouth Sound and of its neighbourhood. Since, in contrast to the amount of research devoted to many of the other groups of animals composing our fauna, little attention has been hitherto bestowed on the Turbellaria, the results of my work show a marked increase in the number of species of this group occurring at Plymouth as compared with former records. More interesting than the numerical increase of the fauna are the relations of these newly-added forms to those inhabiting the Mediterranean and Adriatic seas on the one hand and the Scandinavian on the other.

Of the twenty-five species not hitherto found on our coasts, but now known to live in Plymouth Sound, two—*Vorticeros luteum* and *Cylindrostoma merine*—were already found by Hallez at Wimereux.

The following eleven were previously known, through the researches of Oscar Schmidt, Uljanin, and von Graff, to occur in the southern seas of Europe (*Promesostoma ovoideum* was, however, already known to range to Greenland).

Proporus venenosus (O. Sch.).
Monoporus rubropunctatus (O. Sch.).
Promesostoma ovoideum (O. Sch.).
Promesostoma solea (O. Sch.).
Mesostoma neapolitanum (?), v. Graff.[1]
Hyporhynchus penicillatus (?) (O. Sch.).
Plagiostoma Girardi (O. Sch.).
Plagiostoma sagitta (Ulj.).
Plagiostoma siphonophorum (?) (O. Sch.).
Monoophorum striatum (v. Graff).
Automolos ophiocephalus (O. Sch.).

Eight were previously recorded by Jensen and Levinsen from the coasts of Norway and Greenland respectively, namely—

Aphanostoma elegans, Jensen.
Promesostoma agile (Lev.).
Byrsophlebs Graffi, Jensen.
Hyporhynchus armatus (Jensen).
Plagiostoma dioicum (Metschnikoff).
Plagiostoma caudatum, Lev.
Cylindrostoma elongatum, Lev.
Monotus albus, Lev.

Four are new, namely—

Provortex rubrobacillus.
Plagiostoma pseudomaculatum.
Plagiostoma elongatum.
Automolos horridus.

The results of my investigations on the Turbellarian fauna of Plymouth and its distribution in the Sound have been published in greater detail in (1) the 'Journal of the Marine Biological Association' (N.S., vol. iii., No. 1, May, 1893); and (2) the 'Quarterly Journal of Microscopical Science,' No. cxxxvi., April, 1893, where I have given an account of the British Marine Turbellaria, including descriptions and the synonymy of all species hitherto known to have occurred on our coasts.

July 2, 1893.

II. *Report on the Occupation of the Table.* *By* Mr. Edgar J. Allen, *B.Sc.*

Commencing work at the Plymouth Laboratory on June 3, 1892, I occupied the table of the British Association for six weeks, my stay being prolonged for another month through the kindness of Mr. Robert Bayly, who furnished me with an additional nomination.

[1] The bracketed query indicates that corroboration of the occurrence of these species is desirable.

During this period I was engaged on the study of certain points in the anatomy of larvæ of Decapod Crustacea, more especially of *Palæmonetes varians.* The principal results of the work are published in detail in two papers, which have appeared during the course of the year:—

(1) Preliminary Account of the Nephridia and Body-cavity of the Larva of *Palæmonetes varians*, 'Proc. Roy. Soc.,' 1892.
(2) Nephridia and Body-cavity of some Decapod Crustacea, 'Quart. Journ. Micr. Sci.,' xxxiv., 1893.

The following is an outline of the conclusions arrived at. The green gland commences to develop a lumen about the time of hatching of the larva. The gland then consists of an end-sac and of a short tube which opens externally. The distal portion of this tube subsequently enlarges to form the bladder of the gland, the bladders of the two sides finally uniting in the middle dorsal line, thereby forming the unpaired nephro-peritoneal sac.

In late embryos and in young larvæ a shell-gland is present, consisting of an end-sac and tube, and opening at the base of the second maxilla.

A dorsal sac, completely enclosed by epithelium, is found in both larvæ and adults. This sac, which does not contain blood, lies dorsal to the nephro-peritoneal sac, and extends backwards over the front end of the genital glands. The cephalic aorta lies within this sac.

The dorsal sac is formed as a hollowing out in masses of mesoderm cells, which lie upon either side of the aorta. Two lateral cavities are thus formed, which increase in size and unite below the aorta. From this mode of development it appears probable that the dorsal sac is homologous with the dorsal portions of the mesoblastic somites of *Peripatus*, and hence must be regarded as a true cœlom. The general body-cavity also seems to be homologous with that of *Peripatus*, and to be hæmocœlic in nature.

June 13, 1893.

III. *Report on the Occupation of the Table.*
Notes on How Fish find Food. By GREGG WILSON, *M.A., B.Sc., Edin.*

For a month from August 15 of last year I occupied the table at the Plymouth Marine Station provided for me by the British Association, and during that time I devoted myself chiefly to the study of the feeding habits of fish. In connection with some work that I had done earlier in the year on the Aberdeenshire coast my attention had been called to the practical importance of Bateson's distinction between sight-feeders and smell-feeders,[1] and I desired to repeat and test his experiments, and, if possible, extend his results. I find that his main conclusion is a sound one: there are sight-feeders and there are smell-feeders among the fish; but the distinction is not absolute, and my observations do not in all cases correspond with Bateson's. In a few notes I will summarise my conclusions.

I. *Sight-feeders.*—I found no fish that did not use its smelling powers more or less in the search for food. Bateson's instance of the pollack (*Gadus pollachius*), that usually hunts and feeds, relying entirely on

[1] *Journ. Marine Biol. Assoc.*, vol. i. (N.S.), 1889–90, p. 225.

appearances, but which, when its hunger has been appeased, *noses* its food before eating, is an illustration of, perhaps, the *minimum* use of smell observed by me. Many other habitual sight-feeders make, or can make, much more extensive use of the nose. The well-known fact that stale bait appeals to few of our food-fishes points to this, and my experiments bear it out.

So far as I could determine, fish that are not *very hungry* habitually smell food before taking it. The pollack seems usually to be ready for a meal, and on almost all occasions when anything eatable is thrown into the tank in which it is swimming it rushes towards it, and bolts it. It does not hesitate to take stale food or food that has been steeped in strong smelling fluids; and time after time I have been amused to see its too-late repentance after it had swallowed clams that had been saturated with alcohol, chloroform, turpentine, &c. It is only when it is satiated with fresh food or disgusted with what is nauseous that it takes the precaution to smell before eating. On the other hand, various fish that are equally keen-sighted, and habitually recognise their food by the use of their eyes, are more prudent. The whiting (*Gadus merlangus*), for instance, appears to pay much more attention to smell, and, as a rule, turns about and withdraws on approaching within a few inches of high-smelling objects that the pollack would take without hesitation. Even whiting, however, cease to be delicate if they are very hungry, and if other fish are present to compete for the food that is thrown to them. In such circumstances bait that is very distasteful may be taken by even the most cautious of sight-feeders; and likewise in such circumstances a quite smell-less artificial bait may be successfully employed. Where large shoals of fish are, there are likely to be many that are very hungry, and the consequent keen competition will lead to hasty feeding by sight alone; and hence it is, probably, that lead-baits are successfully employed in cod-fishing in the Moray Firth and off the Northern Islands, while they are of no avail among the scanty fish further south.

It may be said that in these cases the fish actually *search* for their food by sight alone, and merely test the quality of what they have found by smelling it; and Bateson quite recognised this. But more is possible: *habitual sight-feeders can be induced to hunt by smell alone*. The pollack, which is such a pronounced sight-feeder that it will take a hook baited with a white feather or a little bit of flannel and trolled along the surface, is yet able, when blinded, to get its food with great ease. Several blind specimens in the Plymouth tanks were carefully watched by me; and I had no difficulty in deciding that it was by smell alone that they found their food. Their conduct was exactly such as was seen in the smell-feeders, to which I shall presently refer.

Again, the cod (*Gadus morrhua*), which Bateson puts among the sight-feeders, is generally believed—and with good reason, I think—to feed more by night than by day; which suggests that it, too, not only tests its food, but actually hunts by smell.

Lastly, in this connection I would state the results of my experiments. I worked with a number of fish, and always with the same success; but I shall here only refer to one case—that of the dabs (*Pleuronectes limanda*). That they were sight-feeders was evidenced by their behaviour when I lowered a closed tube full of water, and with a worm in the middle of it, into their tank: time after time they bumped their noses against the glass at the very spot where the worm was situated. That they could

also recognise the smell of food, apart from seeing it, was demonstrated in various ways. First, if instead of a closed tube, as in the last-mentioned experiment, one open at the bottom was used, after a short interval the nosing at the part where the worm was seen ceased, and *the lower end of the tube*, from which, doubtless, worm-juice was diffusing, was vigorously nosed. If, again, instead of putting worms into a tube I placed a number of them in a closed wooden box with minute apertures to let water pass in and out, there was a similar excitement produced, and the dabs hunted eagerly in every direction. When water in which many worms had lain for some time was simply poured into the tank through a tube that had been in position for several days, and by a person who was out of sight of the dabs, the results were most marked. In a few seconds hunting began, and in their excitement the dabs frequently leapt out of the water, apparently at air-bubbles, and on one occasion one even cleared the side of the tank, which was about two inches above the water, and fell on to the floor of the aquarium. Yet there was nothing visible to stimulate this quest.

II. *Smell-feeders.*—In the case of the smell-feeders I was also led to doubt the exclusive dedication of the one sense to the task of food-finding. Congers (*Conger vulgaris*) certainly do all that Bateson's paper says of them: they hunt by night; they do not go at once or direct to food that is near them, but after it has been in their neighbourhood for a short time grope around for it, till they gradually approach so near that they touch it; and then they snap at it greedily. They cannot find food that has been washed in ordinary salt-water so as to remove the smell; they hunt when good-smelling fluids are poured into their tank; and they swallow corks or even stones that are suitably flavoured. But I came to the conclusion that the congers in Plymouth Aquarium—and I have no reason for supposing them to be different from other congers—were *practically blind*. I have seen two when hunting come into direct collision with such violence as to produce a loud thud; and once I saw one start back in alarm on coming in contact with a crab that was in its way. I have seen one *lose its prey, and then hunt for it again in the same indirect way as at first*, though it certainly had discovered that the fish was a thing good to eat. Often, too, a conger when close to its food makes a snap in the wrong direction: it is when it *touches* that it snaps successfully. So the sense of sight cannot be very good! There is, however, at least a perception of the difference between light and darkness; and a conger will retreat from a lighted match even by day, and at night will seek shelter when a lantern is exposed.

Unfortunately, though there were plenty of congers in the tanks while I was at Plymouth, other smell-feeders were not well represented. The rockling and sole, however, were available, and I repeatedly made experiments with them. The rockling (*Motella tricirrata*) seems to be a true smell-feeder: it 'hunts' by night; it becomes highly excited when an extract of any of its favourite foods is poured into the water in which it is. Unlike the conger, however, it sees very well, as Bateson himself pointed out. And, more than that, *it can find its food by sight*, though for some reason—perhaps because of the timidity of the fish—this is difficult to observe. Several times I saw appearances that almost demonstrated the fact, and on one occasion the behaviour of a rockling left no room for further doubt. For ten days it had had almost no food, and when, at the end of that time, worms were thrown into its tank, it quite plainly

saw them, and recognised them as food; for it rushed at them and took them while they were still falling through the water. When a number of worms were subsequently put in at once, the rockling swam two or three times rapidly round the tank, taking all that were within reach. As I wrote in my note-book at the time, this is 'clear proof of use of sight.'

As regards soles (*Solea vulgaris*) I got evidence more easily. They see well, and will come forward from far back in a tank when a handkerchief is waved before the glass. I have seen them gather *at once* from all parts of a large tank to feed on worms that were thrown to them; I have seen them rise to take worms that were falling through the water, or to seize without groping or hesitation prawns that were swimming about the tank. So I have no difficulty in deciding that they, too, use sight as well as smell in seeking their food. I confess I cannot understand why Bateson's soles should have failed to find worms that were suspended a little above the bottom. Perhaps they were more nervous than those I had to deal with; or mine may have been educated by the experience of the intervening years!

The Committee desire to conclude their report by expressing the hope that the Association will place in their hands, for use during the ensuing year, the unexpended balance of 15*l*. They believe that competent workers have been materially assisted by being appointed to the free use of a table at the Plymouth Laboratory, while they feel that the latter institution deserves the further support of the British Association.

The Physiological Action of the Inhalation of Oxygen in Asphyxia, more especially in Coal Mines.—Report of the Committee, consisting of Professor J. G. McKendrick, *F.R.S.* (*Chairman*), Dr. J. T. Bottomley, *F.R.S., and* Mr. W. Ernest F. Thomson, *M.A., M.D.* (*Secretary*). (*Drawn up by the Secretary.*)

This Committee was appointed, at the Meeting in Edinburgh, 1892, of the British Association, in order to ascertain, primarily, whether oxygen gas is of any service as a restorative in carbonic-acid poisoning, such as occurs in the form of choke-damp asphyxia in mines. Secondarily, it was considered advisable by the Committee to inquire somewhat into the action of oxygen; first on persons in health, and secondly on those suffering from disease giving rise to retention of carbonic acid in the blood. The Committee, however, do not attach very great importance to their observations of the latter class.

The Committee consisted of Professor McKendrick, Chairman; Dr. J. T. Bottomley, and Dr. W. Ernest F. Thomson, Secretary, by whom the work was carried out, and who has prepared the report.

The general conclusions at which the Committee have arrived are based upon a considerable number of experiments on animals, and some observations on human beings.

The following are the general conclusions:—

I. In the case of rabbits asphyxiated slowly or rapidly, oxygen is of

no greater service than air, whether the recovery be brought about in an atmosphere contaminated by carbonic acid or completely free of carbonic acid, and whether artificial respiration be resorted to in addition or not.

II. Pure oxygen, when inhaled by a healthy man for five minutes, produces no appreciable effect either on the respiratory rate and volume or on the pulse rate and volume.

III. Oxygen, whether pure or somewhat diluted, produced no effect on one particular patient, who suffered from cardiac dyspnœa of moderately severe type, in the direction of amelioration of the dyspnœa; and compared with air inhaled under the same conditions produced no appreciable effect, either on the respiratory rate and volume or on the pulse rate and volume.

IV. An animal may be placed in a chamber, the general cavity of which contains about 50 per cent. of carbonic acid, and retained there for a long time without supervention of muscular collapse, provided a gentle stream of a respirable gas-air or oxygen indifferently be allowed to play upon the nostrils and agitate the surrounding atmosphere.

The points which are not proved are—1st. Whether oxygen produces marked effects, toxic or otherwise, when inhaled for a long time; 2nd. Whether oxygen is of service in cases of cyanosis due to diminished respiratory surface, *e.g.*, in pneumonia; 3rd. Whether oxygen is capable of bringing about the cure of many diseases in which it has received the credit of being a remedial agent.

Finally, since this investigation was primarily undertaken in the interests of the mining community, the Committee are strongly inclined to urge that advantage be taken of the fact, now ascertained, that oxygen is of no greater service than pure air in cases of asphyxia, and that the experiment be made of keeping a few cylinders of *air*, with nose and mouth pieces, ready for use in those parts of the workings where men might be most easily imprisoned. The expense of the compressed air would be much less than that of oxygen, and the effect would be equally good. It seems quite reasonable to suppose that when a suffocated person has to be dragged through a long passage, itself more or less contaminated as regards its atmosphere, the chances of ultimate recovery will be greater if the effects of this poisonous atmosphere be neutralised at the commencement and during the progress of the work of rescue than if no such attempt be made until fresh air be reached in the ordinary way.

The Legislative Protection of Wild Birds' Eggs.—Report of the Committee, consisting of Mr. THOMAS HENRY THOMAS, *R.C.A.* (*Chairman*), Rev. Canon TRISTRAM, *D.D., LL.D., F.R.S.*, Professor ALFRED NEWTON, *F.R.S.*, Professor ADOLPH LEIPNER, *F.Z.S.*, Professor NEWTON PARKER, *Ph.D., F.Z.S., and* Dr. CHARLES TANFIELD VACHELL (*Secretary*). (*Drawn up by the Secretary.*)

YOUR Committee beg leave to report that early in the present session 'A Bill to Amend the Wild Birds Protection Act, 1880,' was brought into the House of Commons by Sir Henry Maxwell, M.P., and others, and that on April 13 it was ordered by the House to be printed. Thereupon your Committee gave this Bill their careful attention, and

found that its main clause contained a provision for the protection of wild birds' eggs. In the opinion of your Committee, however, this provision was framed on a principle that appears to them to be mistaken, in that it sought to effect the desired object by empowering local authorities to name the species the eggs of which were to be protected, thus requiring in every case of prosecution proof of identity, which in the majority of cases would be difficult, if not impossible, to supply. Nevertheless, the Bill met with favourable acceptance in the House of Commons, and with some very trifling alterations only, and without any discussion of its principle, passed the third reading, and was sent up to the House of Lords on May 2. In the House of Lords the chief objection to the Bill, which had already been observed by your Committee, was, among others, prominently brought forward by several speeches in a debate on the second reading, June 14, and accordingly a series of amendments were introduced and carried when the Bill was in committee, on June 16. In almost every point these amendments, and especially one which provided that protection should be given to birds which most required it by empowering local authorities to name areas in which for a given time the taking of eggs should be wholly prohibited, accorded with the opinion at which your Committee had previously arrived. Subsequently, the Bill was further amended by the Standing Committee of the House of Lords, and, having been read a third time, was sent back to the House of Commons for its approval of their Lordships' amendments.

These your Committee, after duly considering them, had hoped would be at once accepted by the House of Commons; but, on August 21, on the motion of Sir H. Maxwell, it was moved that consideration of them should be adjourned for three months, and therefore the fate of the Bill remains doubtful.

In view of the uncertainty thus existing your Committee would recommend their reappointment on the same terms as before.

Index Generum et Specierum Animalium.—Report of the Committee, consisting of Sir W. H. FLOWER, Dr. P. L. SCLATER, Dr. H. WOODWARD, and Mr. G. BROOK (*Secretary*), *for supervising its compilation by* Mr. C. DAVIES SHERBORN.

THIS index, commenced in 1890, was continued by the compiler unassisted until 1892, when the British Association made a grant of 20*l.* in aid of the work. The compilation continues to progress satisfactorily, about 200 volumes having been searched through, and over 10,000 species having been indexed during the past year. The work is extremely laborious, chiefly by reason of the difficulty in many cases of determining the exact date of publication of the book under examination; but the results of the solution of difficult problems of this kind are invariably made public so soon as their accuracy has been satisfactorily proved. Of these results the publication of the dates of Schreber's 'Säugthiere' by the Zoological Society of London in their 'Proceedings' for 1891 may be cited. Of the books examined this year the accurate determination of the dates of the 'Encyclopédie Méthodique' is, perhaps, the most important

result attained. These dates will also be published in the Zoological Society's 'Proceedings.'

The plan of work adopted by the compiler has been favourably commented upon, among foreign specialists, by Professor J. Victor Carus, Professor Sven Loven, and Mr. S. H. Scudder. The Committee ask for their reappointment, with a grant of 30*l.* in aid of the continuance of this most useful compilation.

Scottish Place-names.—Report of the Committee, consisting of Sir C. W. WILSON, *F.R.S.* (*Chairman*), Dr. J. BURGESS (*Secretary*), *and* Mr. COUTTS TROTTER. (*Drawn up by the Secretary.*)

THE Committee have to report that at their suggestion a Place-names Committee of the Royal Scottish Geographical Society was appointed to consider the orthography of the Place-names on the survey maps of Scotland, and specially to revise the spellings in the Gaelic-speaking districts of the country.

This committee, which had power to add to their number, consisted of Professor James Geikie, LL.D., F.R.S., Sheriff Æneas Mackay, LL.D., Professor Julius Eggeling, Ph.D., Mr. A. Silva White, Secretary, R. Scot. Geog. Soc.; and James Burgess, LL.D., Chairman. It met on November 20, 1891, and arranged the forms to be used in collecting information, agreed to appoint local committees in each parish, and to make additions to the committee of gentlemen specially qualified to aid in the work.

After correspondence there were subsequently added to the Committee the following gentlemen:—Rev. Dr. Masson, M.D., Ex-Sheriff Alex. Nicolson, LL.D., W. J. N. Liddall, Esq., Advocate, Sheriff D. Mackechnie, Dr. D. Christison, Professor Blackburn, Hew Morrison, Esq., J. M. Rusk, S.S.C., W. C. Smith, Esq., Advocate, Dr. Bannerman.

The Committee were of opinion that, whilst names referred to them by the Ordnance Survey from Lowland districts might be satisfactorily dealt with by correspondence, personal knowledge, and references to records, it would be desirable to proceed otherwise with the great mass of Gaelic names in Highland districts, and for these it was decided that it would be necessary to prepare lists of all the names in each parish, and to submit them, in the first place, to local or parish committees appointed for the purpose of pointing out and correcting all supposed errors in spelling. The local arrangement of names in the survey books greatly facilitated the identification of the spots intended; and the Chairman was empowered to correspond with ministers and local gentlemen to form such committees. The islands of Islay and Jura were then undertaken, and the following instructions were issued to the local committees:—

DIRECTIONS.

'(1) The Place-names to be revised are written out under Column I. Against those correctly spelt a × should be affixed in Column II. Correspondents will distinguish names of Norse or English origin by adding the initial letter N or E to the × under Column II.

'(2) Those names which are incorrectly spelt should be rewritten, in a clear legible hand, on the same line under Column III. Such corrections should be attested by at least three local authorities in Column IV.

'(3) In those instances where there are alternative forms of spelling the same name, the alternative form or forms should be given under Column III., and attested in the usual way in Column IV.

'(4) Names of Norwegian origin are prevalent, more especially in Arran, Jura, Islay, Morvern, Skye, the Outer Hebrides, &c. The utmost care should be taken to discriminate all such names, and to give under Column III. their proper spellings, *with* or without the Gaelic spellings that may be in use for the same—to be attested in Column IV. Names of Norse and English origin have the generic element *after* the specific, as in Oak-field, Helms-dale, Lidi-strom; whereas Gaelic names almost always have the generic *first*, as Auchindarrock, Glen-shee, Inch-keith.

'(5) Special information by correspondents can be communicated on separate sheets of paper.'

The first lists were for Kilchoman parish, containing about 970 names, and were undertaken by a local committee, consisting of Rev. J. Barnet, Mr. Wm. Campbell, Mr. Donald McGilp, Mr. John Campbell, Rev. James Macmillan, Mr. Neil Orr, Portnahaven; and Mr. John Brown.

These gentlemen did their work with much care and attention, and returned the revised list by June, 1892. The Committee then held frequent meetings in examination of the revised names, and approved of the great majority of the changes proposed.

Meanwhile, the lists for Killarow and Kilmeny, Kildalton and Oa, and for Jura, had been issued. The Killarow and Kilmeny list contained about 940 Place-names, and was undertaken by a local committee, consisting of Rev. John McLachlan, Kilmeny; Rev. Peter Stewart, Killarow; Mr. W. McFadyen, Ballygrant; Mr. P. Macintyre; Rev. P. McIver, Bowmore; Mr. Murdoch McTaggart, solicitor; and Mr. D. Macbean, Public School, Bowmore.

The returns from this parish were discussed by the Committee at meetings held in November and December, 1892.

The list for Jura has not yet been returned. That for Kildalton and Oa contained over 1,200 names, and the local committee were Rev. Wm. Campbell, Mr. Colin Hay, Mr. Lachlan McCuaig, Rev. D. McMaster, Mrs. Ramsay, and Mr. Colin Campbell. This list occupied the Committee at a series of meetings, and was disposed of during the early half of the present year.

From the officers of the Ordnance Survey were also submitted, from time to time, for the opinion of the Committee, local Place-names, such as Auchendinny or Auchindinny; Glencorse or Glencross; Roslin, Roslyn, or Roslyne; Machars or Machers; Rinns or Rhynns; Garwald and Bara or Garwald; St. Monance or St. Monans.

In deciding on the spellings of these and such names the Committee were guided largely (1) by what has been the prevalent spelling in deeds and records of every kind up till a recent date, when names have frequently been altered in spelling in an unaccountable way, possibly through the influence of non-residents, railway and post-office officials, newspaper writers, &c. For postal and other common purposes, it may be quite sufficient to indicate a parish by the single name of 'Garwald'; but the Ordnance map may be regarded and used as legal evidence, and

in united parishes the inhabitants of the portions which formerly were separate parishes may each have burial and other rights of which the double name—Garwald and Bara—is *primâ facie* evidence, and for this and for historical reasons the Committee considered that the full name ought in all such cases to be preserved.

(2) Where more spellings of a name than one have been long prevalent, and about equally so, it may be allowed, especially where local feeling is in favour of it, to adopt that one which is nearer the older or original form. If the people in Wigtownshire prefer 'Machars' to 'Machers,' the Committee could only approve of such a spelling.

(3) On the other hand, they could not attempt to enforce in a case like that of 'Newbattle' (which is well known to be a misnomer) a reversion to a better form unless it were to be acceptable to the proprietor.

(4) The Committee, however, would strongly object to all new and fanciful spellings having no authority in the records of the last three centuries. Some such have crept into our best maps, and have been copied into popular gazetteers, almanacs, and the like: these have seldom any authority, and misrepresent the historical Place-names.

In Gaelic names the Committee had to deal with different circumstances. A large class of these had never appeared in any record; they were so distinctly descriptive of the places that a person understanding Gaelic could make no mistake about their meaning, and the only question was the correct writing down of the name. Gaelic spelling, as well as pronunciation, differs in districts lying apart: the enunciation and spelling of a Ross-shire man will often differ from those of a native of Argyll or Arran. There are also refinements of spelling that good scholars do not consider necessary in Place-names. It has, therefore, been the aim of the Committee not to give prominence to such refinements, but to deal with the names on broad principles. This course the late Sheriff Nicolson, who attended the Committee's meetings very regularly, and with the weight of his extensive scholarship and local knowledge, was ever ready to support. His death during the early part of this year has been a serious loss to the Committee.

In such of the Highland names as occur in valuation rolls and other records there appear to be fully a larger proportion of variants than in the same class of names in Lowland districts, and there was consequently more scope for choice, but also more frequent calls for deliberation and investigation. This made the work more arduous and troublesome, and seemed to demand the services of a person qualified to collect the various forms with the authorities for them to be weighed by the Committee; for it is just this class of names that require the most careful consideration.

The result of the examination of over 3,100 names in Islay has been the revision or correction of about 520, or 16 per cent., of them, varying from about 11 per cent. in Killarow to nearly double that proportion in Kildalton.

The grant of 10*l.* made in 1892 was too small a sum to enable the Committee to engage any needed help, and was kept for stationery, postage, necessary printing, and to procure a good Gaelic dictionary.

Exploration of Ancient Remains in Abyssinia.—Report of the Committee, consisting of Dr. J. G. Garson (*Chairman*), Mr. J. Theodore Bent (*Secretary*), Mr. F. W. Rudler, Mr. E. W. Brabrook, *and* Mr. G. W. Bloxam. (*Drawn up by* Mr. Bent.)

Appendix.—*On the Morphological Characters of the Abyssinians. By* Dr. J. G. Garson.

The Committee have received the following report from Mr. Bent :—

The four months which I was able to pass in Abyssinia at the beginning of this year have been very productive in ethnographical research. We were able to visit the sites of ruins at a spot called Yeha and at Aksum, the ancient capital of this part of Ethiopia, and when there to take a large number of photographs and impressions of inscriptions which throw a flood of light on the origin of the Ethiopian race and language, and leave no shadow of a doubt that both are derived in the first instance from an ancient Arabian stock, namely, early Sabæan traders, who built themselves fortresses and temples in the Abyssinian mountains, and left there traces of their writing and their art as far back as the eighth century B.C.

About five hours' ride from Adoua, in a north-easterly direction, we visited the village of Yeha, where is a very ancient temple preserved to us by the fact that it has been a religious centre in Abyssinia, and has thus been protected from the depredations of marauders. The building is a very fine specimen of ancient art, built with large 'drafted' stones, and crowning a knoll which commands the surrounding village and plain, hemmed in on all sides by stupendous mountains. Here, too, we found nine Himyaritic inscriptions, which Professor D. H. Müller, of Vienna, has deciphered, and which date back to the eighth century B.C. One of these gives the name of the place as Ava, and besides this we have two references to this place Ava—one given us by Nonnosus, who went as ambassador from Justinian to the king of Abyssinia in 540 A.D., and another from the Adulitan inscription, probably about the first century of our era. Both these agree in placing this town of Ava on the ancient trade route between Adulis and Aksum, and consequently there is no doubt whatsoever that the ruins of Yeha originally formed the town of Ava, and that it was a Sabæan colony from Arabia which settled here for the purposes of trade at a very remote period.

Professor Müller connects this temple of Ava with the worship of Baal Ava, common at that period in Southern Arabia; and the nature of the building, the monoliths adjoining it, the altar, and other facts too numerous here to mention obviously connect this ruin with early Sabæan sun-worship; and from its strength, decoration, and position we can clearly see what a strong foothold the merchants of Arabia had gained in Abyssinia many centuries before the commencement of our era. The neighbourhood of Yeha is very fertile, and this fertility was accounted for by the inhabitants from the fact that in the mountains behind they possess caves in which they can store their goods out of the way of marauders, and hence the valley of Yeha is one of the most prosperous and fertile in Abyssinia. It is a curious fact that Ava was probably the capital of this district, known to the earliest geographers as Ethiopia Troglodytica, or that part of Ethiopia where the inhabitants dwelt in caves; it is just

possible that these very caves above Yeha may have been the origin of the term.

Aksum is about forty miles inland from Yeha, and after the destruction of Ava was for many centuries the capital of the Aksumite kings, and subsequently of the emperors of Abyssinia. In subsequent years Aksum was abandoned as the political centre of the country, and gave place to Gondar, and now to Ankoba in Shoa; but it has always remained as the religious capital of Abyssinia, the sacred city of the Ethiopians. Owing to the disturbed state of the country we were only able to spend ten days there, instead of two months, as we had originally intended; but in those ten days we were able to amass a large quantity of valuable archæological material; to take squeezes of the various early Ethiopian inscriptions, some of which had only been indifferently copied before, and others are new to science; to take photographs of the various ruins still standing; and to make a few excursions in the neighbourhood.

I can only give here the actual results of our work, and say what the objects we found definitely prove: First, the long line of monoliths form an excessively interesting study in rude stone monuments. We have at Aksum the monolith in all its several stages of development, from the rudest unhewn stone stuck in the ground like those at Yeha; then we have one with notches on it, another divided into storeys with beams carved thereon; and finally the highly finished monolith, with an altar at its base, a door carved above this, and nine storeys represented on the stone with imitation windows, and divided from one another by beams which are also cut in the stone: these nine storeys culminate in a representation of the heavenly luminary, and point to what the worship was which originated them, namely, the old Sabæan sun-worship; and these decorated monoliths represent the Bethel, or house of God, in its most finished conception. The altars below are of very finished work, and were made to fit tightly on to the monolith: one is surrounded with a well-known Himyaritic pattern, and has holes in the centre for the reception of the blood of the slaughtered victims; another has steps in it and receptacles for the blood, carved in the representation of Greek vases, with channels cut for the blood to run down each of the steps on to the ground. There is no doubt about it that at Aksum existed a form of Mithraic worship which came from Southern Arabia, and was introduced by the Himyarite merchants, who traded with the interior for ivory, gold, and other rare produce valued in the ancient market.

There are about seventy of these monoliths in and around Aksum, some elaborately worked, others mere unhewn stones. Two of the largest, decorated like the one above described, with an imitation door and storeys, are fallen and broken into colossal fragments: they are both considerably larger than the standing one, and must have been very imposing objects when erect. Another monolith, 27 feet high, and presumably of later date, shows a curious Greco-Egyptian influence in its decoration: it had a representation of a Greek tomb or temple *in antis* at the top, supported by an Ionic column made in the form of a lotus, with the two little ivy leaves on either side so characteristic of Greek art in the first centuries before and after Christ. This Greek influence at Aksum is especially remarkable, and may be easily accounted for by the Greek influence and enterprise which were felt in the Red Sea after the conquests of the Ptolemies and the opening out of commerce. Adulis was the port of this commerce, and Aksum seems to have been the capital of the

district to which the tribes from the interior brought their commodities. Greek architecture and art are therefore easily accounted for at Aksum. It is a thoroughly Greek idea to decorate the unsightly unhewn rude stone monuments, and, curiously enough, the realistic idea of carving doors, windows, beams, and storeys is traceable to Greek art in Lycia, Caria, and the southern provinces of Asia Minor. Then we have the altars with Greek vases carved thereon; tombs with the *dromos* and chambers for sarcophagi constructed of huge stones just like those found in Greece. Rock-cut steps cover the hills behind Aksum, just as they do in Greek cities; rock-cut tombs and fragments of architecture recall at many points remains in an old Greek site. Early geographers tell us of this influence, and that the kings of Aksum spoke and studied Greek; and then finally we have the bilingual inscription in which King Aizanes of Aksum records his victories on one side in Greek and on the other in early Ethiopian in the fourth century of our era. One can thus readily understand how the way was thus opened in Ethiopia for the Christian missionaries from Alexandria, and that Ethiopia was one of the first affiliated branches of the early Christian Church.

The inscriptions which we brought from Aksum are of a later date than those of Yeha, but show at the same time the Himyaritic script generally developing into early Ethiopian, and form a very valuable series from this point of view, incontestably proving the origin of Ethiopian, and that it is a survival to us of the early form of speech and writing which was found in the early Sabæan and Himyaritic empire in Southern Arabia.

Professor D. H. Müller has been hard at work for some weeks past on these inscriptions and has developed much material of value. Two of the inscriptions are quite new to science, and the others are read correctly for the first time, having previously been copied by travellers ignorant of the complicated script; but our impressions have now enabled Professor Müller to produce a correct rendering of them as they stand.

Some of the principal points of value which have resulted from this study are, first, definite proof of the origin of the Ethiopian language, and that it is a development or rather a dialect of Himyaritic. Secondly, that the Ethiopians were pagans at least down to the fourth century after Christ, worshipping the same gods as the early Arabians, and thus the Ethiopian legend that they belonged to the Jewish religion from the time of Menelek, the supposed son of Solomon by the Queen of Sheba, is absolutely without foundation, and is probably a fantastic story invented by the early Christians of Ethiopia, which, whilst it acknowledges their Arabian origin, at the same time identifies them with the chosen people of God. The grounds for this story, which have had weight even with observers of modern times, are the existence of certain forms and ceremonies akin to Judaism amongst the Ethiopians, which they owe doubtless to their common Semitic origin. Another point made clear by the inscriptions is the origin of certain curious pedestals, which apparently in former years carried metal statues, and of which there are between twenty and thirty at Aksum. It appears from the inscriptions that the kings of Aksum after a victory set up a throne in honour of it, which they placed under the protection of their three gods, Astar, Medr, and Barrats. Some were decorated with statues, others were plain, and near them was stuck up the dedicatory stone; and lastly Professor Müller proves that the Ethiopians called their country Habaset long before the

modern Arabians called it Habesh, which was supposed to be given it owing to the mixture of the race. Hence the derivation of the name Abyssinia is thus: Sabæan name Habaset, Arabian Habesh, which the Portuguese gave to the world as Abessini when speaking of the inhabitants, which we finally have made into Abyssinia.

After visiting Aksum we went to the site of another set of ruins on a lofty isolated plateau, now known by the Italians as the Altapiana di Kohaito; here we found the remains of a very extensive town with a curious lake in the centre of it, the waters of which were preserved in an artificial reservoir by a wall or dam built of huge stones without cement, and obviously of a very ancient date. This well was 219 feet across, and the centre part, 99 feet long, was built very strongly with 'throughs' and steps to withstand the force of the water. On either side of this stronger portion of the dam were two sluice gates, 5 feet wide, and the construction of this wall corresponds in many ways to the wall or dam at Mareb, the ancient Mariaba, or capital of the Sabæan kingdom in Southern Arabia. This is the chief feature of interest amongst the ruins. Around the lake are the scattered remains of many buildings, temples, houses, and so forth; the columns and capitals of the temples are interesting as connecting the style of architecture exactly with that in use at Adulis, the port of this part of Ethiopia. The columns are square with a groove cut at each angle, and the capitals are also square in three tiers.

This ancient town, long since abandoned, is easily to be identified with the Koloe of the early geographers; in fact, the locality as placed by the Periplus of the Red Sea, namely, three days from Adulis and five from Aksum, is exactly where it should be, and probably it was a summer resort of the rich merchants of Adulis: it is situated at an elevation of 7,000 feet above the sea, and enjoys a most salubrious climate. The plateau is curiously isolated from the surrounding mountains, and the approaches to it are now exceedingly difficult; but there are ample traces of ancient roadways and sustaining walls long ago ruined. Immediately in the valley below, just on the ancient trade road between Adulis and Aksum, there are the ruins of another village with a few columns of a temple still standing of precisely the same form of architecture as that at Koloe and Adulis, and this village would appear to have been a halting place for the caravans on their way into the interior at the foot of the hill on which Koloe was built.

These are amongst the most prominent points of the archæological discoveries we made in Abyssinia, which I hope shortly to develop at greater length with the collaboration of Professor D. H. Müller.

With regard to the anthropology of the Abyssinians of to-day our results were naturally considerably hampered by not knowing the language, and having to obtain our information second hand from an interpreter. However, I think we have been able to arrive at several points of interest, more especially in connection with the quaint and interesting form of Christianity which is the national religion of the country.

In the first place the Christianity of Abyssinia is obviously one grafted on a form of paganism closely akin to sun-worship. As we find in Greece innumerable instances of the way the early divines grafted Christianity on to the existing paganism of Greece and Rome, blending the saints and customs of Christianity with the gods and rites of the old

pagan religion, so we find in Abyssinia obvious traces of sun-worship as the peculiar form of religion which had to give way to Christianity.

In the first place all the churches are round, with four doors oriented to the four points of the compass. They are all surrounded by an outer enclosure, which is thickly planted with trees, and corresponds to the sacred groves so associated in our minds with Baal-worship.

During the Lenten fasts the services are always conducted at night, and cease immediately at sunrise; the peculiar ritual of dancing without which no service in Abyssinia is complete—dancing to the tune of an instrument exactly corresponding to the *sistrum* of ancient Egyptian days—is a trace of the dancing which formed an integral part of Baal-worship.

The great Abyssinian Church ceremony of Mascal, or the raising of the Cross, which takes place in September, is accompanied by the lighting of bonfires at night on all the neighbouring heights and the sacrifice of oxen and other animals. The second great Church ceremony is the blessing of the waters at Epiphany and the baptizing of the Cross, thus honouring water as the next great element after the sun in the process of natural generation. As a curious side proof of this theory may be mentioned an illustration given in an Ethiopian catechism as an illustration of the mystery of the Trinity. 'The Godhead is like the sun, consisting of three parts joined in one and indivisible, namely, rotundity, light, and heat.'

The points in the Abyssinian ritual which have favoured the supposition that they belonged to Judaism before Christianity was preached amongst them are these: The construction of their churches with an outer circle, corresponding to the court of the Gentiles; an inner circle, to the court of the Levites; and the Holy of Holies, where the Ark and the tables of the law are supposed to be kept, with its veil hanging before it. Secondly, the abstention from eating the same unclean animals which the Jews abstain from. Thirdly, the practice of circumcision. Fourthly, their calendars and feasts curiously correspond. I take it that the first and last are purely accidental, and that the third and fourth are common to all Semitic races; and certainly the inscriptions from Aksum exclude all possibility of Judaism having existed in the country as the national religion prior to Christianity.

Another feature which we noticed particularly with regard to the Abyssinian Church is its strict adherence to the orthodox or Greek ritual, and the antagonism which reigns still, and always has reigned, against the tenets of Rome and Western Christianity. As in Greece, the priesthood is divided into monastic priests and working or village priests. The dignities of the Church are reserved for the former: they never marry, and live their useless lives on the top of isolated mountains. The village priest, who performs the services of the Church, may marry before he is ordained, and not after—just like the Greek priests—and he never can aspire to any of the more lucrative positions in the Church. The pictures of the Abyssinian Church are distinctly Byzantine in character, exceedingly grotesque, but offering points of comparison to the work done on Mount Athos. Their legends, superstitions, and quaint beliefs all correspond to those of the Eastern Church; and naturally this is to be expected, as the Abyssinian Church is an affiliated Church of the Alexandrian patriarchate, and is governed by an *abouna* sent out from the Coptic Church of Cairo. But it shows in a remarkable manner the

tenacity with which the customs and ritual of early Christianity have been maintained, and the absolute failure of the Portuguese Jesuits to bring Abyssinia under the dominion of the Pope is aptly parallelled by the absolute failure of the Roman Catholics to obtain a foothold in Greece, and bring about a union of the Eastern and Western Churches.

Nearly everything one comes across in Abyssinia has an interesting pedigree from the old world. The *shamma*, or cloak, they wear is neither more nor less than the old Roman *toga*: it is worn in precisely the ancient manner, with the right hand buried in the folds and the end thrown over the shoulder. The musical instruments they play are similar. The long trumpet played at games and festivals was well known in the ancient world as the *tuba*. The *sistrum*, or rattle, I have already alluded to. The Abyssinian harp is exactly like its old classical prototype, the *lyra*. We still find the rounded sounding-board, made in the form of a tortoise-shell, the ancient *testudo* of the lyre: out of this come the two *cornua*, and the strings are not touched with the fingers, but with *plectra*. The fly-flap used by the priests is exactly like the fly-flaps depicted on the Egyptian tombs. Children up to the age of puberty wear *bullæ*, just as Roman children did. Every Abyssinian has his thorn-extractor, made of pliable metal, like the *volsellæ* of Roman times. The popular Abyssinian game, played on a sort of board with holes, something akin to draughts, is commonly found wherever Arabian influence has been felt all over the coast line of the East, in Asia and Africa alike. The umbrella, and the dignity attached thereto, is distinctly old world. The sacred arcana are always carried under gorgeously decorated umbrellas; only a prince may wear a red one, grandees wear white ones, and peasants go to market with umbrellas made of straw. There is hardly anything in Abyssinia which is not a well-authenticated relic of a bygone civilisation, as the few instances which I have given here will show.

We took the measurement of some fifty Abyssinians, according to the rules and regulations set down by the Anthropological Institute. These measurements have been placed in the hands of Dr. Garson, who has undertaken to work them out.

I hope in the ensuing winter to visit Southern Arabia, with a view to following up the same line of study, both archæological and anthropological. I feel confident that if Southern Arabia be submitted to a careful examination we shall there find traces of an exceedingly primitive civilisation; traces of an empire which existed many centuries before our era, which spread down the east coast of Africa south of the Zambesi, and constructed the ruined buildings visited by us last year in Mashonaland, and which, as Professor Müller shows, are built on exactly the same principle as those of Mareb and Sirwah in Southern Arabia, and were probably used for the same form of religion.

This year we have found traces of an Arabian occupation of Arabia as far back as the eighth century before our era in the mountains of Abyssinia. As discovery follows discovery I am sure we shall be able to reconstruct the history of a once mighty commercial race, which was contemporaneous with the best days of Egypt, Greece, and Rome, and which provided the ancient world with most of its most valued luxuries.

APPENDIX.

On the Morphological Characters of the Abyssinians. By J. G. Garson, *M.D.,* V.P., *Anthrop. Inst., Corresp. Memb. Anthrop. Soc. Paris and Berlin.*

The data for this paper are a series of observations made by Mr. J. Theodore Bent during his expedition to Abyssinia on 46 male natives between the ages of twenty and forty years, 22 of whom belong to the Tigré tribe, 12 to the Ambara tribe, 4 to the Hamasan tribe, 1 to the Bogos tribe, 6 to the Galla tribe, and 1 to the Barea tribe. The first four tribes are members of the Himyaritic group of Semites, the Gallas are Hamites, and the Barea are one of the unclassified tribes.

The colour of the skin of the Himyaritic tribes is generally a rich chocolate, but sometimes cases of a dark yellow-brown or dark-olive hue occur. The Gallas are generally darker, being usually of a sooty-black colour; the Barea is also sooty-black. The eyes are dark, and a vestige of a frænum occurs in many cases at the inner angle of the eye. The hair is black and curly. The profile of the nose is uniformly straight. Prognathism of the mouth is generally very slight or entirely absent, except in the Gallas, where it is more marked than in the others. The lips are of medium thickness, but are somewhat thicker in the Gallas than in the other tribes. Platyprosopism, or flatness of face, predominates throughout all the tribes, but is slightly more marked in the Ambara than in the others.

The cephalic index varies from 64 to 88, but chiefly centres between 76 and 79, the mean index of the series being 78·5, which places them in the mesaticephalic group. In the Amhara tribe it averages 81·4, in the Tigré 78·2, in the Gallas 79. The module of the head averages 158, as obtained from the length, breadth, and height of the calvara added together, and, after 15 mm. has been added to represent the distance from the meatus to the basion, divided by 3; from the length and breadth added together and divided by 2 it is 165. The nasal index averages in the Tigré 68·1, in the Amhara 74·2, and in the Gallas 76·2. According to Broca's divisions of this index in the living, the Tigré are leptorhine and the others are mesorhine.

The mean stature of the series is $1^{m}\cdot693$, the shortest being $1^{m}\cdot593$ and the tallest $1^{m}\cdot870$. The Amhara tribe averages about 2 cm. taller than the Tigré. The trunk, neck, and head are 50·3 per cent. of the stature, and the lower limbs from the level of the tuberosities of the ischia downwards are 49·7 per cent. of the stature. The canon of proportion of the various parts of the body to the height are as follows: Trunk, 32 per cent.; neck, 5·3 per cent.; head, 13 per cent.; the thigh, from the level of the tuberosities of the ischia, 23·2 per cent.; the leg and height of foot, 26·5 per cent.; the length of the foot, 14·5 per cent.; the entire upper limb, 44·9 per cent., the upper arm being 17·2 per cent., the forearm 16·2 per cent., and the hand 11·2 per cent. The length of the forearm to that of the upper arm gives an index of 96; while the leg and height of foot together give, with the portion of thigh from the ischial plane to the knee, an index of 114·3.

Although the tribes examined are all members of the Caucasian family, the Gallas and the Barea are more negroid in their characters than the Semitic tribes, probably from longer contact with the negro and

from the geographical position they occupy in South Abyssinia. Of the Semites the Amhara are more negroid than the Tigré, while the latter retain more of the characters probably typical of the inhabitants of South Arabia, the country which their language indicates as the original home from which they have migrated.

The Exploration of the Glacial Region of the Karakoram Mountains.—Report of the Committee, consisting of Colonel GODWIN-AUSTEN (*Chairman*), Professor T. G. BONNEY (*Secretary*), *and* Colonel H. C. B. TANNER.

THE Committee were appointed for the purpose of assisting in the exploration of the Karakoram Mountains, physically, geologically, and biologically, by Mr. W. M. Conway and companions.

Previous to the expedition of Mr. Conway's party to the Karakoram Mountains the whole of the Gilgit territory had been surveyed and mapped by parties of the Survey of India. Colonel Godwin-Austen, when making his survey of Baltistan in 1860 or 1861, had surveyed up to the Gilgit and Hunza-Nagyr frontier, while Captain Brownlow, R.E., and other assistants of the Kashmir Survey had roughly sketched from very distant points the Gilgit valley. Subsequently Colonel Tanner and two sub-surveyors had made a detailed survey of Gilgit and surrounding valleys. The latter work was published some twelve years back, on the scale of 2 miles = 1 inch, under the title of 'New Map of Astor and Gilgit.' The Bagrot valley and all the southern waterways from the Rakapushi chain were entered on this map, and the spurs of Rakapushi, extending W. and N.W. down to the Gilgit River, were also laid down with fair accuracy. Mr. Conway's exploration this side includes country already well known and surveyed, though his examination of the Bagrot glacier should be considered new and more detailed work. In the new map of Astor and Gilgit the glaciers were coloured green by hand, but not drawn hard with pen and ink on the original map, copied by photography and photozincoed.

Colonel Tanner's work was a continuation to the westward of Colonel Godwin-Austen's survey, and was picked up (with a small hiatus) from that officer's most northerly and westerly stations of observation. On the publication those features not laid down from actual and accurate survey were entered in dots as a guide to any surveyor who might follow Colonel Tanner's party.

The exploring party in the Karakoram Mountains in 1892 consisted of Mr. W. M. Conway, Lieutenant the Hon. C. G. Bruce, Mr. A. D. M'Cormick, Mattias Zurbriggen (an Alpine guide), and four Gurkha sepoys. For part of the time they were accompanied by Messrs. Roudebush and Eckenstein, also by Colonel Lloyd Dicken.

The party reached Gilgit, on a tributary of the Indus, and made their first exploring expedition up the Bagrot valley, since the highest ranges were as yet (May) inaccessible owing to the amount of snow still unmelted. Working on a larger scale, the features of the higher ground, particularly the glacier, were much improved in detail, and the names of all the tributary glaciers recorded. An attempt to cross from it into

Nagyr over the main ridge was defeated, so the party returned to Gilgit. Some interesting observations were made on the mud avalanches in this region. These are vast masses of mud, thickly mingled with huge blocks of rock, which are swept down the gorges in the steep mountain flanks on to the more level parts of the valley, and become important factors in modifying this part of the earth.

Departing again from Gilgit, the travellers visited the rock-bound valley of Hunza-Nagyr. The weather was unpropitious, but another attempt (not completely successful) was made to reach the Bagrot pass from this northern side, and an expedition was undertaken to the Barpu glacier. One branch of this was explored and mapped, and a peak which rises at its head was ascended. The ridge separating this tributary (Barpu) valley from the main Hispar valley was traversed by a pass about 16,000 feet above sea-level. From the latter valley the most important glacier expedition was undertaken, for the Hispar pass (17,600 feet) was crossed to Askoli, which was reached on July 26, nearly a fortnight having been spent on or by the side of the two great glaciers, which stream from the summit (gained on July 18). Their combined length is about sixty-seven miles, and they both terminate at some 10,000 feet above the sea-level.

Askoli was left on July 31 for an expedition to the great Baltoro glacier, and a good view was obtained of K_2 (or Mount Godwin-Austen) (28,278 feet), which rises grandly from the upper part of this ice-region. Pioneer Peak (22,500 feet), a minor summit of the Golden Throne at the head of the Baltoro glacier, was climbed, as well as a lower (Crystal) peak.

The party returned to Askoli on September 5, and crossed southwards from that place by the Skoro pass (about 17,000 feet) to Askoro, in the Shigar valley, whence they reached Skardo on the Indus. From it they visited Leh, and regained Abbotabad (whence they had begun their journey to Gilgit) after an absence of seven months.

Mr. Conway has added some 600 square miles of quite new topography east of Hunza-Nagyr and north of the Rakapushi range up to near the longitude of the Nushik La. Hence his route-map up the Hispar glacier, down the Biafo, and on again to the Baltoro is based on and kept in proper position by the topographical work of the Indian Survey on the 4-miles-to-the-inch scale, executed in 1860–61 (previously alluded to), very much enlarged, showing consequently a great deal of close detail either sketched in on the spot or taken from photographs. The portion near the Hispar pass, never before crossed by any European travellers, has thus been very accurately laid down. He has also corrected the topography of the tributary glaciers at the head of the Baltoro, which Lieut.-Colonel Godwin-Austen when making his survey of it was only able to plane-table roughly from a distance of fifteen to twenty miles.

This detail work of Mr. Conway covers about 1,200 square miles, and is an instructive piece of Alpine topography, because the scale is large enough to show the extent and proportions of the ice and snow-covered surface, and the size and position of the lateral and median moraines, &c.

Many photographs were taken, and a number of sketches were painted by Mr. M'Cormick. The following collections were made: (1) A large number of rock specimens representative of the geology of the districts explored. These are being examined by Professor Bonney, who hopes to

communicate an account of them to the Royal Society next session. (2) A collection of dried plants (sent to the Kew herbarium), of seeds, of which forty species are now growing at those gardens, and of some iris-bulbs. (3) About one hundred specimens of butterflies, sent to the British Museum (South Kensington). (4) A collection of spiders, beetles, &c., was also made, but the greater part of this, unfortunately, was stolen from the baggage on the journey down from the mountains. Some account of the details of the journey has been given by Mr. Conway to the Royal Geographical Society, and has appeared in their journal for November 1892 and for February and July 1893, and a fuller narrative will be published in a volume in the course of a few months.

The Teaching of Science in Elementary Schools.—Report of the Committee, consisting of Dr. J. H. GLADSTONE (*Chairman*), Professor H. E. ARMSTRONG (*Secretary*), Mr. S. BOURNE, Dr. CROSSKEY, Mr. G. GLADSTONE, Mr. J. HEYWOOD, Sir JOHN LUBBOCK, Sir PHILIP MAGNUS, Professor N. STORY MASKELYNE, Sir H. E. ROSCOE, Sir R. TEMPLE, *and* Professor S. P. THOMPSON.

YOUR Committee have the satisfaction of reporting this year two important circumstances which show the increased value set upon the teaching of science in elementary schools. The one has reference to the rapid advance in the adoption of 'Elementary Science' as a class subject; the other is the great provision made for it in the new Code for evening continuation schools.

The report of last year showed the commencement of the movement for the substitution of scientific teaching in the place of the so-called 'English' as a class subject, a movement which has now become much more pronounced. It will be seen by the following tables that, while the teaching of 'English' steadily rose with the gradual increase in the number of schools, that of geography and elementary science slightly decreased during the years 1882 to 1890; and that when the obligation to take 'English' had been removed these two scientific subjects took a start at once, which has been more than maintained in 1891–92.

The number of departments of schools in which these class subjects have been examined by H.M. Inspector during the eight years 1882 to 1890 has been as follows:—

Class Subjects.—Departments	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89	1889–90
English	18,363	19,080	19,431	19,608	19,917	20,041	20,153	20,304
Geography	12,823	12,775	12,336	12,055	12,035	12,058	12,171	12,367
Elementary Science . .	48	51	45	43	39	36	36	32

The numbers during the last two years are as follows:—

Class Subjects.—Departments	1890–91	1891–92
English	19,825	18,175
Geography	12,806	13,485
Elementary Science	173	788

The number of scholars examined in the scientific specific subjects during the eight years 1882–90 has been as follows :—

Specific Subjects.—Children	1882–83	1883–84	1884–85	1885–86	1886–87	1887–88	1888–89	1889–90
Algebra	26,547	24,787	25,347	25,393	25,103	26,448	27,465	30,035
Euclid and Mensuration	1,942	2,010	1,269	1,247	995	1,006	928	977
Mechanics A	2,042	3,174	3,527	4,844	6,315	6,961	9,524	11,453
" B	—	206	239	128	33	331	127	209
Animal Physiology	22,759	22,857	20,869	18,523	17,338	16,940	15,893	15,842
Botany	3,280	2,604	2,415	1,992	1,589	1,598	1,944	1,830
Principles of Agriculture	1,357	1,859	1,481	1,351	1,137	1,151	1,199	1,228
Chemistry	1,183	1,047	1,095	1,158	1,488	1,808	1,531	2,007
Sound, Light, and Heat	630	1,253	1,231	1,334	1,158	978	1,076	1,183
Magnetism and Electricity	3,643	3,244	2,864	2,951	2,250	1,977	1,669	2,293
Domestic Economy	19,582	21,458	19,437	19,556	20,716	20,787	22,064	23,094
Total	82,965	84,499	79,774	78,477	78,122	79,985	83,420	90,151
Number of scholars in Standards V., VI., and VII.	286,355	325,205	352,860	393,289	432,097	472,770	490,590	495,164

The numbers during the last two years are :—

Specific Subjects.—Children	1890–91	1891–92
Algebra	31,349	28,542
Euclid	870	927
Mensuration	1,489	2,802
Mechanics	15,559	18,000
Animal Physiology	15,050	13,622
Botany	2,115	1,845
Principles of Agriculture	1,231	1,085
Chemistry	1,847	1,935
Sound, Light, and Heat	1,085	1,163
Magnetism and Electricity	2,554	2,338
Domestic Economy	27,475	26,447
Total	100,624	98,706

It will be noticed that the very rapid increase which took place in 1890–91 has not been quite maintained; the diminution has been principally in algebra, animal physiology, and domestic economy, while there has been a great increase in mensuration and mechanics. Estimating the number of scholars in Standards V., VI., and VII. at 500,000, the percentage of the number of passes in these specific subjects as compared with the number of children qualified to take them is 19·7; but it should be remembered that many of the children take more than one subject for examination. The following table gives the percentage for each year since 1882 :—

In 1882–83	29·0 per cent.
„ 1883–84	26·0 „
„ 1884–85	22·6 „
„ 1885–86	19·9 „
„ 1886–87	18·1 „
„ 1887–88	16·9 „
„ 1888–89	17·0 „
„ 1889–90	18·4 „
„ 1890–91	20·2 „
„ 1891–92	19·7 „

The returns of the Education Department given above refer to the whole of England and Wales, and are for the school-years ending with August 31. The statistics of the London School Board are brought up to the year ending with Lady Day, 1893. They show still more strikingly the advance that has been made in the teaching of elementary science as a class subject, and they give the number of children as well as the number of departments.

Years	Departments	Children
1890–91	11	2,293
1891–92	113	26,674
1892–93	156	40,208

The only alterations in the Code of this year which directly affect the instruction of the children in elementary schools, and which come within the scope of this Committee's inquiries, are the addition of dairy work and housewifery as recognised subjects of instruction for girls. These are capable of being so taught as to be scientific in character, the first named being necessarily experimental, and no grant being receivable unless special and appropriate provision has been made for its practical teaching. No grant is given as yet for housewifery.

With respect to the Queen's Scholarship Examination, which is now the final examination of pupil teachers, it is provided that marks will be given for a pass in certain specified science subjects at the May examination of the Science and Art Department, instead of for a first class as heretofore. Hygiene and physics are added to the list of subjects for which marks may be given, thus allowing a greater range of choice, though only one science subject will count for this purpose. There is, however, a footnote added to the effect that 'after the present year marks will not be given at any examination for a pass at any examination held more than a year previously.' Now, as the Science and Art Department's Examinations are held in the month of May, and those for the Queen's Scholarship at the end of June or beginning of July, it is evident that, in order to gain the marks offered, the pupil teachers must take the two examinations in the same year, and that within two months of each other. This will be injurious to both, and cause an unnecessary pressure upon the candidates, who have hitherto been able to take their qualifying certificates under the Science and Art Department in the earlier years of their pupil-teachership. Your Committee have pointed out in previous reports that there is no obligation upon pupil teachers to learn any science during apprenticeship, although they may actually be required to teach object-lessons or elementary science in school. These marks are

the only incentive offered by the Government, and the new regulation will tend to diminish the study of science at all. Your Committee also lay much stress upon the continuous training of the mind by scientific study during the whole period of apprenticeship, instead of cramming up simply for a pass at the close. Marks will also be given now 'to candidates who shall present University Extension certificates awarded by the University of Cambridge, the University of Oxford, the Victoria University, and the Universities Joint Board of the London Society for the Extension of University Teaching, provided that the certificates shall have been awarded (after examination) during the year preceding the Queen's Scholarship Examination on a course of study including not less than twenty-four lectures and classes (of which the candidates must have attended not less than twenty) in one of the following subjects,' amongst which are specified 'geology, astronomy, meteorology.' It appears, however, to be a hardship that some subjects in which Extension lecture certificates can be gained should be excluded, *e.g.*, that a pupil teacher attending lectures and doing practical work in chemistry cannot make use of the certificate so obtained in passing the Queen's Scholarship examination.

In the preceding report of your Committee it was pointed out that evening schools had made great progress, in consequence of greater liberty having been given in the choice of subjects—a matter which your Committee had strongly advocated in former years. This development has since assumed still larger proportions, as will be seen by the following table. It should be borne in mind, however, that the Government returns do not show how many of these passes are made in scientific subjects.

Evening Scholars taking Additional or Special Subjects.

Years	Scholars Examined				Passes Made			
	In One Subject	In Two Subjects	In Three Subjects	In Four Subjects	In One Subject	In Two Subjects	In Three Subjects	In Four Subjects
1889–90	8,973	6,053	—	—	7,101	5,454	—	—
1890–91	13,281	12,717	1,317	232	12,071	11,846	1,488	364
1891–92	17,357	17,675	1,413	286	16,469	17,392	2,127	464

It was pointed out in the last report that the schemes for instruction in scientific subjects given in the Code for 1892 were unsuitable, as they were constructed on the assumption that evening scholars would go through a course extending over seven years. The Code has been entirely remodelled this year, and from every point of view it presents great improvements upon all preceding regulations. The new ideas contemplated by the Committee of Council on Education are indicated in the change of name to 'Evening Continuation Schools,' which are no longer restricted by any age limit, adults of any age being now recognised as scholars. Individual examination, which has always been deterrent to the elder students, is now entirely abolished, and the grants payable by the Government will be assessed on the result of inspection without notice, at which observation of the manner in which the lessons are given will be an important factor in judging the merit of the school. This alteration will of itself greatly conduce to the more intelligent handling of the subjects taught, and to the formative character of the work.

A choice is given from about forty different subjects of instruction, some of these being for women only. About one half of these are either directly or indirectly of a scientific nature, and each scholar may take not less than two or more than five of these subjects. They include—

(*d*) Mathematics	Euclid, Algebra, Mensuration,
(*e*) Science subjects, and subjects of practical utility	Elementary Physiography, Elementary Physics and Chemistry, Science of Common Things, Chemistry, Mechanics, Sound, Light, and Heat, Magnetism and Electricity, Human Physiology, Botany, Agriculture, Horticulture, Navigation,

together with domestic economy, cookery, laundry work, dairy work, housewifery, and manual or technical instruction. There is the restriction that no scholar may take more than two of the science subjects for a grant. This the Committee take to mean the subjects specified in category (*e*), so that two of those might be taken *plus* the three mathematical subjects (*d*) or three of the miscellaneous subjects, domestic economy, cookery, &c. As most of these latter may, and indeed ought to, be taught upon scientific principles, the limitation may not in effect be of any serious consequence; while the last of all, 'Technical Instruction,' may be made to include the practical application of the several physical sciences included in category (*e*).

The various schemes suggested in the Appendix are much too detailed to admit of being introduced into this report, but it may be mentioned that while those for most of the subjects of instruction follow pretty closely on the lines of those in the day schools Code, though not apportioned to particular stages or as work for separate years, there are detailed schemes given for some of the subjects which are far in advance of anything that has hitherto been supplied by the Education Department. Of these the courses of instruction prescribed for elementary physiography, elementary physics and chemistry, agriculture, and domestic economy are given in great detail. To that for elementary physics and chemistry, which is described as an elementary course in practical science, a memorandum is appended to the following effect:—'The second title is given to this scheme to indicate that it is not a mere outline of a set of lectures, but is rather a systematic course of practical instruction for the scholars themselves. The complete set of experiments should be carried out by the class (*i.e.*, the scholars) as a whole. The whole course may reasonably extend over two or even three years.'

Your Committee are glad to recognise in this the adoption of the principles which were laid down in their report read at the Cardiff meeting in 1891, and hope that the improved methods of instruction suggested in the continuation school Code may be largely adopted in the elementary day schools.

Reference was made in the report of this Committee in 1891 to the appointment of additional science demonstrators by the School Board for London, and to the fact that these demonstrators were endeavouring to initiate practical work by the scholars in a number of schools under their charge. Two years' experience has shown, not only, as was to be expected, that the children take the greatest interest in such lessons, in which they are led to gain information through their own observations and experiments, and to draw conclusions therefrom, but that it is possible, even under the present admittedly unfavourable conditions, to accomplish much valuable work of this character; and, in fact, the scheme which has been introduced into the Evening Continuation School Code is largely based on the experience thus gained in the London School Board.

Moreover, experience has shown that the ordinary teachers are capable of carrying such a scheme as that put forward in the Evening Code into execution, after receiving the necessary special instruction, provided that they are thoroughly supervised and aided by constant inspection; and such a method of instruction and supervision of the teachers has been recognised in the Code of 1893 (Section I. 5*, p. 2). It is to be hoped that County Councils may be led to give help in these matters, as their work would be much forwarded by such instruction in scientific method being given to those whom subsequently they specially wish to reach.

Finally, your Committee urge that no time should be lost in extending instruction in measurement, &c., such as is indicated in the Evening Code, to girls' schools, as the habits which can be acquired through such instruction are precisely those which are of importance in carrying on household work.

The Methods of Economic Training adopted in this and other Countries.—Report of the Committee, consisting of Professor W. CUNNINGHAM (*Chairman*), Professor E. C. K. GONNER (*Secretary*), Professor F. Y. EDGEWORTH, Professor H. S. FOXWELL, Dr. J. N. KEYNES, *and* Mr. H. HIGGS.

YOUR Committee have succeeded in obtaining a quantity of interesting information from French, German, Italian, Austrian, Spanish, Belgian, Dutch, Russian, and Scandinavian universities, as well as from the United States and Canada, but much of it has been so delayed that it has not been possible to draft a complete report for the present meeting.

While deferring, therefore, the presentation of its detailed report until next year, your Committee wish to express their conviction of the unsatisfactory conditions attending economic instruction in this country.

As compared with the better equipped among the foreign countries with which comparison would naturally be challenged, the inferior organisation of teaching in the United Kingdom is very striking. For this there seem to be two main causes:—

(1) The omission of many teachers to adequately recognise methods of empirical study.

(2) A very prominent and present cause—the practical exclusion of Economics from the curricula and examinations preliminary to those professions in connection with which its study would appear peculiarly

suitable. The importance of applied Economics has not been sufficiently recognised either in university or in Government examinations.

Before presenting a fuller account of the inquiries undertaken on their behalf, and of the methods whereby in their opinion desirable changes might be effected, your Committee desire further time for consideration. For this purpose they ask for reappointment.

The Climatological and Hydrographical Conditions of Tropical Africa.—Second Report of the Committee, consisting of Mr. E. G. RAVENSTEIN (*Chairman*), Mr. BALDWIN LATHAM, Mr. G. J. SYMONS, *F.R.S., and* Dr. H. R. MILL (*Secretary*). (*Drawn up by* Mr. E. G. RAVENSTEIN.)

THE Committee held five meetings and carried on the double work of supplying instruments to competent observers, and collecting the records of meteorological observations already made in tropical Africa.

Sets of instruments have been supplied (1) to Dr. W. H. Murray for use in Nyasaland (on account of the observer's health breaking down, these instruments were left in store at Ke'limani, and transferred to Mr. J. Buchanan); (2) to Mr. Moir in Nyassaland; (3) to the Rev. Mr. Glennie at Bolobo, on the Congo; (4) to M. Bonzon, on the Ogowe; and (5) to Captain Gallwey in Benin. Of these, Mr. Moir's and Captain Gallwey's sets have been erected in their permanent positions, and Captain Gallwey has commenced to send in regular monthly sheets. A sixth set of instruments has been acquired for the use of the Rev. Mr. Morris, of British East Africa.

Records of previous work have been received since last report from the Rev. Mr. Glennie (at Bolobo, on the Congo) for two years, from Fort Salisbury, and from eight stations in British East Africa.

Forms for recording meteorological observations and copies of the 'Hints to Observers' drawn up by the Committee have been supplied to many observers in different parts of Africa.

The Committee's instructions have been adopted by the Royal Geographical Society, and incorporated in the new edition of 'Hints to Travellers.'

Your Committee have expended the 50*l.* granted, and they beg to propose that they be reappointed, and t ha a grant be made of 25*l.*

The Dryness of Steam in Boiler Trials.—Report of the Committee, consisting of Sir F. BRAMWELL (*Chairman*), Professor W. C. UNWIN (*Secretary*), Professor A. B. W. KENNEDY, Mr. MAIR RUMLEY, Mr. JEREMIAH HEAD, *and* Professor OSBORNE REYNOLDS.

OWING to various circumstances the Committee are not in a position to report at this meeting. The subject is one of some importance, and some new methods of testing the dryness of steam have lately been proposed. The Committee ask, therefore, to be reappointed, with a view of preparing a report for the next meeting.

The Development of Graphic Methods in Mechanical Science.—Third Report by Professor H. S. Hele Shaw, *M.Inst.C.E.*

Graphical Solution of Problems.

The first and preliminary report on this subject was presented in 1889. The second report was presented last year, and was divided into four parts.

1. General geometrical considerations.
2. The representation of results graphically.
3. Graphical solution of problems.
4. A tabulated list of reference to graphic methods to be found in the scientific literature of this country.

Only a brief treatment of the third division was possible. This included quotations from various authors concerning the development of the subject and a summary of graphical problems, though a more complete account was given of two of these branches, viz., slide rules and mechanical integrators.

The present Committee was appointed to prepare a third report on the subject, dealing as completely as possible with the unfinished portion of the report, viz., 'The Solution of Problems.'

The study of the second report, particularly of the classified list of references, conclusively shows that graphical solutions have in this country at any rate proceeded almost entirely on two lines.

1. Interpolation of plotted results.
2. Use of reciprocal diagrams in structures.

The former, although arriving at results which would be difficult, if not impossible, to obtain in any other way, is itself a remarkably simple operation, the chief part of the work really consisting in the preparation of the diagrams in which the interpolation is made. This matter was treated very fully in the second report, both for plotted curves and instrumental methods for obtaining them.

The latter, viz., use of reciprocal diagrams, is largely employed, chiefly because of its simplicity. It forms, however, only one branch of what is now known as 'Graphical Statics,' which in turn only includes one class, although the most important class of graphical problems. Moreover, the cases treated by its means are nearly always the simplest, and do not involve the use of more complete solutions which have been given by various writers for cases of more difficult problems in structures. There has been, however, a large amount of research in connection with the subject, of which little practical use is at present made, and while, on the one hand, many writers strongly advocate the application in practice of graphical statics (*vide* 'Quotations,' pp. 420–426, second report), on the other hand there is a large amount of scepticism as to the use which may be derived from the study of the subject.

What is apparently needed is a definite statement of the general nature of graphical operations followed by a concise account of the

solutions of the various engineering problems at present scattered over various books and papers in English and foreign literature. This should convey a clear idea of the problems which can be dealt with, so that their practical use can be estimated. The bare statement of the problems would, however, be scarcely sufficient for this purpose, since not only must the problems be such as are required, but the solution must not be too difficult, or the ideas too abstruse for practical engineers. Some application to practical results would, therefore, be advisable, leaving, however, as a general rule, the proofs and explanation to be derived from the works which are quoted. This important work cannot be attempted so as to do justice to it in the present report, which merely gives a classified outline of the problems.

It is not to be expected that the graphical methods will come into general use unless special training and education on the subject can be obtained at technical colleges and schools. As a good deal has been said and written on this subject (*vide* second report), this report has been supplemented with an account of the teaching of graphical methods in engineering schools at home and abroad as explained on p. 608.

The following is an outline of the scheme of the present report:—

Division I.—Graphical Operations in General.
Division II.—Summary of Problems which have graphical solutions.
Division III.—The Teaching of Graphical Methods.

Division I.—Graphical Operations in General.

As already noted, graphical operations are distinguished from mere geometrical operations by the fact that definite portions of lines represent quantities, and only such geometrical operations are of interest as enable definite numerical results to be obtained.

It is true that a very common graphical operation is that of finding the direction of the line in which the resultant of various given forces act; but direction itself, though it may not always be numerically expressed, is capable of being so expressed if required. Indeed, it is this particular power of being able to deal directly with the directions in which forces act, or motion takes place, and with positions in space, instead of first translating these measurable quantities into mathematical symbols and calculating the results by means of trigonometry or algebra, and finally effecting their reconversion into some geometrical mode of representation, that constitutes the great value of graphical methods. It is this that has led to the discovery of the solution of such a large number of engineering problems and its growing popularity amongst scientific men.

We may treat graphically many problems in which direction or position is not either of them the factors which actually occur, but in which they simply become a part of the process of performing mathematical operations; thus treatises on graphic statics frequently commence by stating the means by which multiplication, extraction of roots, solution of equations, &c., may be graphically performed. It is tolerably clear that the reason why the operation of these numerical calculations by graphic methods has never been put to any practical use is because such work is most easily performed arithmetically.

The problems which arise in engineering are, however, to a large

extent connected with the action of force and the motion of bodies in space, in which cases direction and position are direct factors in the problem. In the great majority of cases the action of such forces may be practically taken as in space of two dimensions, and therefore capable of direct representation upon a plane surface; but it is satisfactory to know that the resources of graphic methods are equally capable of dealing with cases in which three dimensions of space must be considered, and that, by the aid of descriptive geometry, drawings on a plane surface may be made to completely represent the conditions of such problems. Indeed, the fundamental property which underlies the whole of graphical operations employed for the solution of problems, viz., 'reciprocity,' has very similar interpretation, at any rate in mechanics, both in two dimensions of space and in three. In any case, however, it is a plane surface which is operated upon, and the question as to what can be done with a plane surface as regards quantities represented or dealt with upon it must be considered.

Upon a plane surface we can represent the position of a point, and, supposing the point to move, we can further represent its path by a line or assemblage of points, any given portion of which has a definite numerical length. In every position that the point takes along the line it has a definite direction, and the direction of the motion of the point, or, as it is commonly called, the 'direction' of the line, for that position of the point can also be stated as a definite numerical quantity. These properties of direction and length, as already noted (*vide* second report), are equivalent to a knowledge of the position of points on a surface. It is these numerical properties which give the means of graphical operation, because without such properties being introduced the operation would be purely geometrical. Sometimes we may require as the solution of a problem only one of these, as, for instance, length, in a mere problem of graphical calculation. Sometimes another property may be required, *e.g.*, direction, as in the case of the line of pressure in an arch, or the slope at any point of a bent girder; but in all cases we employ two at least of these properties in the graphical solution of a problem.

It may scarcely be remarked that although we may actually operate with straight lines we obtain by their intersections assemblages of points giving curves of various orders, or, what amounts in the limit to the same thing, envelops, the straight lines being then tangents to the curve. The distinction between these two ways of regarding curves, although important in geometry, does not present itself very prominently in graphical problems.

The direction of a line at any point may be always supposed to be about some centre, real or imaginary, to which it may be referred, no matter what curve the line may take. In practice, however, the lines used for graphical operations are chiefly limited to the case when the centre is at infinity, that is, to straight lines. The reasons for this are obvious, for straight lines of limited length or 'segments' are readily measured, and have a constant direction, which is easily expressed. Arcs of circles in some cases might be employed, for the curvature is constant; but no curve offers the same advantages for the general purposes of graphical manipulation as a straight line. There is another and deeper reason for the use of straight lines or rows of points, viz., the fact that forces act, and bodies tend to move in straight lines, and hence the

problems in connection with the most important physical phenomena are necessarily performed by operations with straight lines.

Operations with straight lines or segments have been classified under heads and collected into books. One of the earliest writers to do this was Culmann, and the first chapter of his work, 'Die graphische Statik,' published in 1866, has the title, 'Operations with Lines,' and contains the following headings:—

1. Addition and subtraction.
2. Multiplication and division of lines with ratios.
3. Powers and roots.
4. Multiplication of lines with lines.

Other writers[1] practically adopt the same classification, and it will be well, in order to save repetition, to take his statements for consideration.

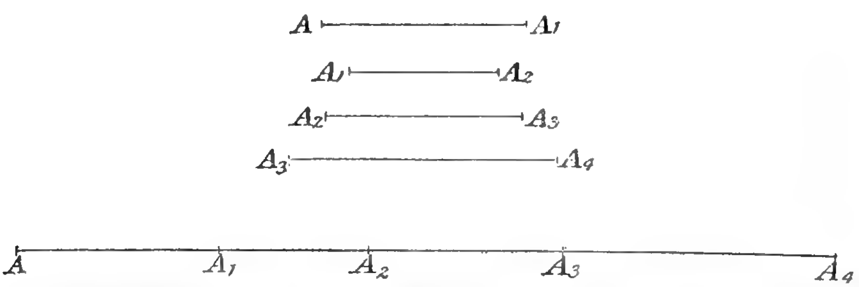
This classification practically divides the subject into—

1. Addition.
2. Multiplication.

Now there exists between these two processes, as set forth by the writers in question, a radical distinction which does not exist between the ordinary arithmetical processes under the same names.

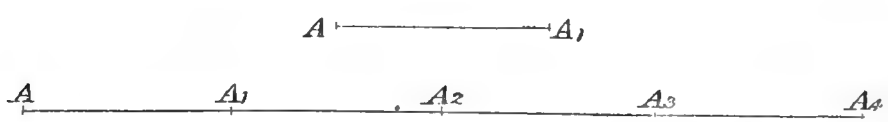
To illustrate the latter let the segment A A_1 (fig. 1) be taken, and let us add to it any number of segments. This operation is shown in the figure, the sum or result being A A_1 A_2 A_3 . . . A_n.

FIG. 1.



If, however, we wish to take any multiple of the segment A A_1, say n times, then the product or the result is shown in fig. 2 as the length of the segment A A_1 . . . A_n.

FIG. 2.



These two operations correspond to the arithmetical ideas of addition and multiplication. But in arithmetic we have a definite process for the

[1] Amongst writers on the subject may be quoted:—Cousinery, *Le Calcul par le Trait*, Paris, 1840; Eggers, *Grundzüge einer graphischen Arithmetik*, Schaffhausen, Vienna, 1868–69; Jäger, *Das graphische Rechnen*, Speyer, 1867; Von Ott, *Die Grundzüge des graphischen Rechnens*, Prague, 1879; Favaro, *Sulle prime operazioni del Calcolo grafico*, Venice, 1872; Bellavitis, *Considerazioni sulla Matematica pura*, Venice, 1872; Cremona, *Elementi di Calcolo grafico*, Turin, 1874.

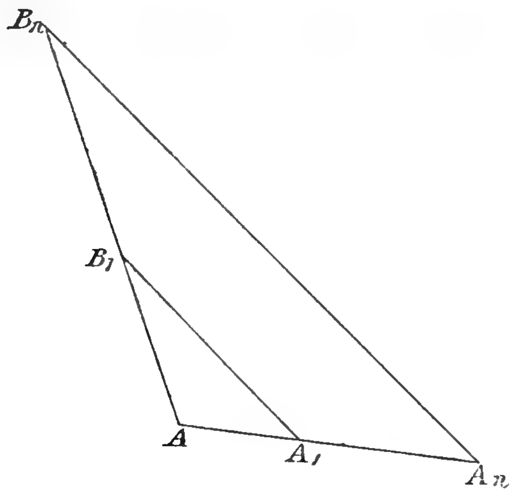
performing of multiplication, the graphical analogue of which is as follows:—

At any arbitrary angle to the given segment $A\ A_1$ (fig. 3) set off a segment, $A\ B_1$, of unit length and produce it to B_n, so that $A\ B_n=n$ units of length. Join $A_1\ B_1$, and through B_n draw $B_n\ A_n$ parallel to $A_1\ B_1$, meeting $A\ A_1$ produced in A_n.

Then

$$A\ A_n=A\ A_1\times n=A\ A_1\ A_2\ .\ .\ .\ A_n.$$

FIG. 3.

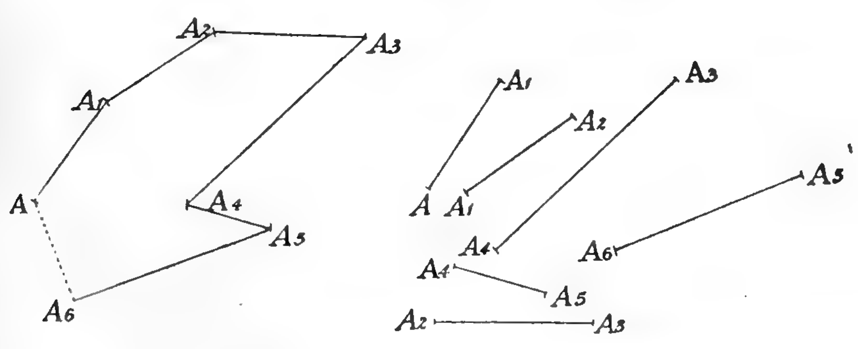


This process, it will be noted, necessitates the employment of the two dimensions of a plane surface, but only gives results involving one dimension, as the direction is quite an arbitrary matter.

Culmann and other writers, however, do not limit the idea of addition to parallel segments, but extend it as follows:

Let it be required to add the segments $A\ A_1$, $A_1\ A_2$, . . . fig. 4, now no longer parallel. The process of doing this is shown, and $A\ A_6$ is said to be the graphical sum or result of the operation. This idea is

FIG. 4.



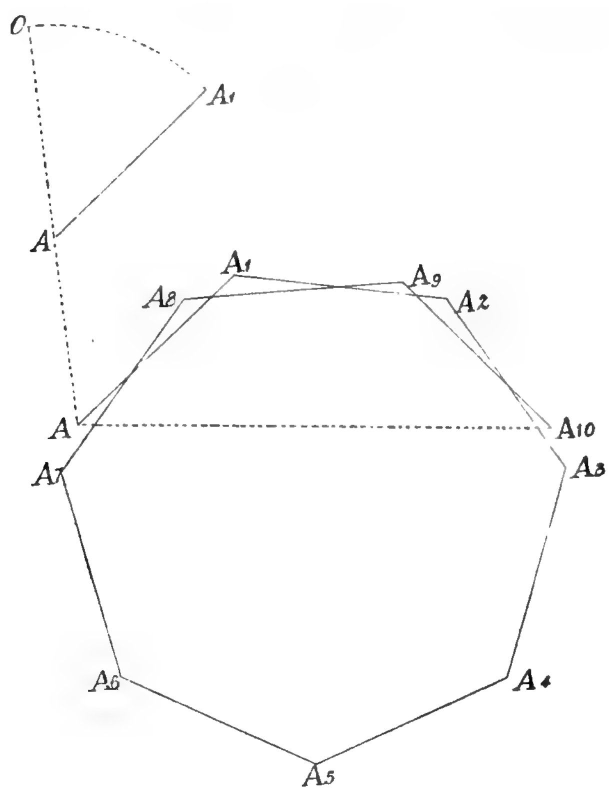
extended to three dimensions of space; thus Culmann says: 'The lines may have any direction whatever in space, and the figure can then be looked upon as a projection upon the paper. If such a combination of

lines should really be made, two such projections would be necessary to determine the position and length of the resultant, and the lines would have to be projected according to the rules of descriptive geometry.'

Now the foregoing operation on a plane surface really involves the addition of two independent variables, viz., length and direction, being equivalent to taking the actual position in space of two dimensions of each successive point, instead of in space of one dimension, as in the first case. The result, which gives the final position of a point in the plane, also involves two measurements, which may be expressed as the length of a segment, and its direction relatively to a line. If three dimensions of space be used, then the operation involves three independent variables, and the results may be also expressed as such in terms of either three distances from three fixed points, or as one distance and two directions with fixed planes.

We look in vain for any analogous operation given in books under the heading of graphical multiplication. The above process, although extended so as to meet the various requirements for which it is employed, is the only other means of graphical operation. We may, however, suggest a corresponding process by which a segment A A_1 having length and direction may have both these magnitudes multiplied ten times, and

FIG. 5.



this can be done as shown in fig. 5. Here A A_1 is the given length, and O A A_1 the given angle. The successive segments, A A_1, A_1 A_2, A_2 A_3, . . . are set off at the given angle to each other, starting from A A_1.

The nature of the operation evidently gives only the total length and total angle made by the segments. The length and direction of the 'resultant' segment, $A A_{10}$, have no meaning.

This case makes it clear that the true sum in the case of addition, and the product in the case of multiplication, must be taken for length along or parallel to the line itself, whilst the resultant angle must be considered to be that turned through by a line passing through A, which occupies positions successively parallel to the various segments. Now, in the so-called graphical addition we get neither one nor the other of these quantities, but a certain measure of each. Concerning this Culmann says: 'As resultant or sum of this addition we must naturally consider the final point of one such line. Hence in the case when all the lines have the same direction, the distance of the final point will be equal to the sum or difference of all the lines,' but the sentence goes on to say: 'Just as it is impossible to take from the sum of several magnitudes the value of a separate magnitude, we cannot here obtain from the position of the final point alone those of the separate segments,' which looks strongly as if the writer felt there was some radical difference, which, however, he does not define. The difference between the two things is, however, really the key to the whole subject, the process of graphical addition being really of two separate kinds which are mixed up together, one involving only one kind of thing, and corresponds to simple arithmetic, and the other involving the use of two dimensions of space and two kinds of quantities, and leading to the most important graphical results. It seems not advisable to consider the latter as a simple matter of graphical addition. In this report, therefore, the words 'graphical addition' will be limited to what appears to be really its legitimate use, and the expression 'graphical combination' will be employed to express the idea of combining non-parallel segments, the word 'sum' being employed to signify the result in the former case, and the 'resultant,' as usually employed, retained solely for the latter. In the case of multiplication, where two dimensions of space are already used to perform the multiplication, only the simple arithmetical idea is involved.

A recognition of this difference leads to a clear view of the actual nature of problems in which the same figures and construction may be used to find the magnitude and direction of the resultant segment, and also at the same time to perform the multiplication of the given segments by quantities which may depend upon their relative positions. It is therefore necessary, before proceeding further, to consider the question of multiplication. In Culmann's work (second edition), page 7, a statement is made under the heading 'Multiplication and Division of Lines by Ratios.'

'We distinguish two cases in the multiplication and division.

'The multiplication or division of lines by ratios. In this case the degree is not altered, and the result is a line.

'The multiplication of lines by lines, which gives surfaces, and of surfaces by lines, which gives volumes, &c., and inversely the division of volumes by lines, which produces surfaces, and so on. In this case there is a change in the degree.'

The first of these, viz., the operation of multiplying by a ratio of the value n, is the same as taking the segment n times in the way already explained. It is true that Culmann says:—

'In many cases one considers the case where the ratio is given by a

number, and if one gives for a multiplier the length 1, 2, 3, . . . n, one carries it 1, 2, 3, . . . n times upon a line. This method, although very simple, does not entirely harmonise with the methods of graphic statics. Graphical construction can only give lines and not numbers, and, more, one can only carry out graphical construction by means of lines. To carry n times the same length upon a line is equivalent to translating the given number into a line, exactly as the measuring off and plotting of the last line correspond to the translating of the closing line into the result. We will therefore always suppose that the ratio of the factor is expressed by means of two lines, m and n.'

This really means that, as already seen, the actual method of obtaining graphically the product of a line must be by means of a graphical operation, which operation has been shown to be by the use of similar triangles, in which the multiplier figures as a ratio which from our point of view is $\frac{n}{1}$.

With regard to the second division this is studied in two separate chapters under the respective titles of 'The Transformation of the Reduction of Areas' and 'The Transformation of Volumes.' The first edition of the above work had as a heading of one division, 'Multiplication of Lines by Lines,' the contents of which practically amounted to the reduction of areas to lineal representation, although another chapter relates to the surfaces and volumes. Now the statement that the multiplication of lines by lines gives surfaces cannot be admitted without some qualification. It may perhaps be convenient to use such an expression, but geometrically this is not really true, and may prove very misleading in graphic statics. From any point of view multiplication simply consists in a process of addition, and no addition of lines can possibly give an area. What the idea arises from is of course evident, for an area may be regarded as the mean length of a figure multiplied by the mean breadth, simply because unit of area is a surface which may be regarded as of unit dimension in each of the above directions, and therefore any other area contains the number of units of area represented by the product of mean length and breadth. Lines may represent these two quantities, and in this sense alone may be regarded as being multiplied together.

Thus an indicator diagram, in which length and breadth respectively represent volume and pressure, may be said to show the product as foot-pounds of work, but this is only because a unit of area on the diagram represents to scale a unit of work, or 1 foot-pound. The total area is given by the product of the two quantities representing mean pressure and mean volume.

The foregoing considerations may thus be summed up as indicating the manner in which the remainder of this section will be treated.

(1) Segments are the means by which graphical operations are chiefly performed, the result being either the final length or direction of a segment. Therefore quantities must be reduced to segments before they can be dealt with. Hence area and volume must be represented by straight lines, and the means of doing this will be considered first.

(2) Addition is confined to segments in one direction, *i.e.*, to continuous straight lines, or parallel segments.

(3) Multiplication is the operation of adding graphically a given number of equal segments, but requires the use of two dimensions of space to be practically useful in the solution of problems. Thus multipli-

cation is limited to finding length, although it might be applied to multiplying an angle if practically useful, both operations, however, not being performed simultaneously.

Representation of Areas and Volumes by Means of Segments.

It may be assumed that any concrete quantity to be dealt with by a graphic operation is given in terms of a numerical quantity, and may be at once represented to some scale by a 'segment,' [1] understanding by this word, unless qualified (as, for instance, segment of a *circle*), some definite distance between two points; that is, the length of a straight line.

A geometrical quantity, however, in the form of a curved line, or of an area or volume, has frequently to be dealt with, and this must first be represented by a segment. There are means of calculating such areas or volumes, and in the second report a section was devoted to the mechanical means of doing this. It is, however, necessary to have methods of doing this graphically, and such methods are generally treated, not only in books on graphic statics, but in treatises on descriptive geometry.

Areas may be divided into polygons and figures bounded by curves. The former may be always reduced to a single triangle by the well-known method of drawing successive parallels. The area of any triangle may in its turn be represented by a segment equal to the altitude of another triangle, of the same area as the former, but with a base equal to twice the unit of length. The polygon need not, however, be reduced to a triangle, and there are various methods which avoid doing this, although the principle of the operation is the same in all cases.

If the boundary be curved the figure can be split into a polygon bounded by the curved figures, which may be supposed to be segments of parabolas. Now, the segment of a parabola is $\frac{4}{3}$ the area of a triangle, upon the same base and of the same altitude, and therefore by making triangles upon each parabolic sector, having their altitudes respectively $\frac{4}{3}$ that of the parabola's segment, and adding them all to the original polygon, the operation of reducing the area of the figure becomes merely that of reducing the new formed polygon.

A special case is that in which the bounding curve is an arc of a circle, the area of which is occasionally required; as, for instance, in the case of an arch, the extrados and intrados of which may have different centres. In this case the first step involves finding a segment equal in length to an arc, or, as it is called, the 'rectification' of the arc, which is also occasionally required in other graphical problems. Rankine suggests two methods, in one of which a tangent is drawn at one extremity to meet a radial line through a point on the arc a quarter of its length from that extremity. The sum of the distances from the two extremities to the above point differs from the length of the arc by a distance (r being the radius).

$$d=\frac{(\text{arc})^5}{4320r^4}+\frac{(\text{arc})^7}{3484648r^6}+\ \cdot\ \cdot\ \cdot$$

This construction requires the centre of curvature of an arc.

The other method does not require the centre of the curvature, but

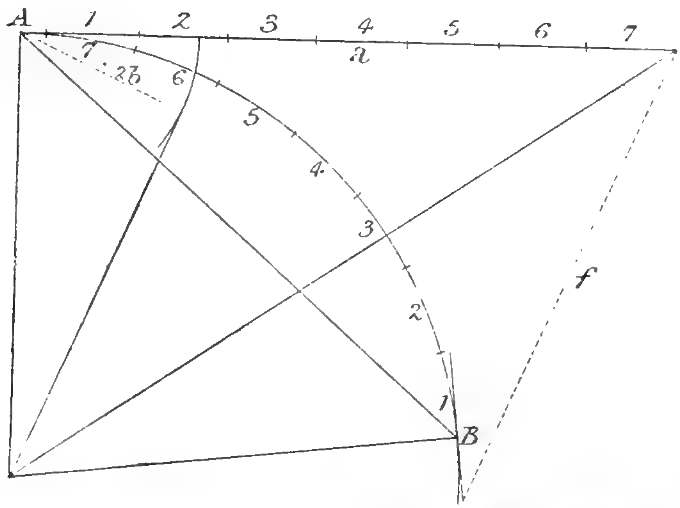
[1] Some American writers use the term 'sect,' and this term, though open to objection, is perhaps even less so than 'segment,' which has generally been used for a different kind of geometrical quantity.

consists in producing the chord of the arc to a point, half its own length distant, and with this point as centre, and with a radius equal to $\frac{3}{2}$ of the chord, drawing an arc to meet the tangent at that extremity of the arc which is nearer the centre. The length of the tangent so intercepted differs from the actual length of the arc by a distance.

$$d=\frac{(\text{arc})^5}{1080r^4}+\frac{(\text{arc})^7}{54432r^6}+\ \cdot\ \cdot\ \cdot$$

Culmann states that 'the only practical method of setting off an arc along a tangent is to plot a chord the same number of times both along the arc and along the tangent, and to add the final remainder' (this

FIG. 6.



operation being indicated in fig. 6), and remarks that this raises the question as to how great an arc must be chosen in order that the error should not be greater than d when an arc a is measured by the plotting of the chord l along it. The difference between an arc and its chord is

$$\frac{a^3}{4.6.r^2}-\frac{a^5}{4.6.8.10.r^4}+\ \cdot\ \cdot\ \cdot$$

this being obtained by expanding from $2r\sin\frac{a}{2r}$ and subtracting from the arc a (r denoting the radius of the arc). The error d therefore is $\frac{l}{a}$ times this difference, since the arc a has been plotted $\frac{l}{a}$ times along l. We have therefore

$$d=\frac{l}{a}\cdot\frac{a^3}{24r^2}=\frac{a^2l}{24r^2},$$

the arc a being chosen so small that the second member of the difference may be neglected with regard to the first; in which case

$$a=r\sqrt{\frac{24d}{l}}.$$

Hence it follows in practice that $\frac{1}{200}$th of an inch (say $\frac{1}{216}$ in.) will be sufficiently accurate, and if this value be substituted for d we get

$$a=\frac{r}{3\sqrt{l}},$$

where l is in inches; then if the arc to be measured is 4 in. long, a must be taken $\frac{r}{6}$ in.; but if it be 25 in. long, then must

$$a=\frac{r}{15}\text{ in.}$$

Culmann recommends that a should never be chosen smaller than is required by these formulæ; for by plotting off the chord too many times the accuracy due to the smaller difference between the arc and chord is again lost.

He remarks that this method is much more exact than attempting to divide the arc into a certain number of equal parts. He also mentions the method published by Herr Hanacek in the 'Zeitschrift des Oesterreichischen Ingenieur und Architecten Vereins,' 1871, which is really the construction of a length from the following formula:—

$$s=2\sqrt{l^2+f^2}+\frac{f^2}{3l},$$

when chord of $\frac{1}{2}$ arc $=\sqrt{l^2+f^2}$, and $\frac{f^2}{3l}$ is the segment of the base of a right-angled triangle whose height is f (*i.e.*, the height of the arc), the other segment being $3l$, where $2l$ is the chord of the arc.

Culmann remarks about the method: 'It is more practical and more correct to take the length a, by means of which we measure an arc so small that it should not require any correction, which is better than to measure half the length of the arc, having to correct this measure beforehand.' He also shows that the above formula when expanded gives

$$s=2l\left(1+\frac{2}{3}t^2-\frac{1}{8}t^4+\frac{1}{16}t^6-\quad . \quad . \quad .\right),$$

where

$$t=\frac{f}{l};$$

whereas the correct value is really

$$s=2l\left(1+\frac{2}{3}t^2-\frac{2}{15}t^4+\frac{2}{35}t^6-\quad . \quad . \quad .\right),$$

and by means of an example proves that for a semicircle the error is inadmissible.

Cremona, however, remarks about Culmann's method ('Graphical Calculus,' English translation, page 114): 'The method given by Culmann for developing the circular arc A B along the tangent at one of its points is much too long. The length of the circular arc may be found graphically in a much simpler fashion by having recourse to auxiliary curves, which drawn once for all can be employed in every example,' and proceeds to give the methods suggested by Professor A. Sayno, of Milan,

for two of which the spiral of Archimedes is employed, and in the third the hyperbolic spiral.

Lastly, there is a method of rectifying the semicircle given by Kochanski, about 1685 (see Cremona), in which an angle at 30° laid off at the extremity of a vertical diameter meets the tangent to the latter from the point of intersection; along the tangent a distance equal to three times that of the radius is taken, giving a point whose distance from the extremity of the vertical diameter is

$$l = r\sqrt{4 + (3 - \tan 30°)^2}$$
$$= 3{\cdot}14153r.$$

Using one of the foregoing methods for finding geometrically the length of an arc, the area of the sector of a circle can now be found by drawing a tangent to the arc equal to it in length and joining the extremities of the segment with the centre. The area of the triangle so found is equal to the area of the sector.

Culmann has compared the difference of area resulting from the assumption of a parabolic arc or of a circular arc as the approximate form of the bounding curve of an area.

Let F_1 = the area of a circular segment.
F_2 = " " parabolic "

$$F_1 = 4lf\left(\frac{1}{3} + \frac{1}{1.3.5}t^2 - \frac{1}{3.5.7}t^4 + \frac{1}{5.7.9}t^6 - \ \ . \ \ . \ \ .\right)$$

and $$F_2 = \frac{1}{3}fl$$

(f, l, and t having the same values as previously),

the difference $$F_1 - F_2 < \frac{4}{3}\,lh \times \frac{1}{5}\,t^2,$$

$$\text{or } < \frac{1}{4}\,t^2 \times F_1.$$

Therefore if $$f = \frac{1}{10}\,l$$

the difference $$< \frac{1}{100}\,F_1.$$

In the reduction of volumes to segments the same principles and constructions are employed as in the reductions of areas.

Thus, if

$$V = \text{volume} = \text{area} \times l$$
$$= bhl,$$

where b, h, and l are respectively the breadth, height, and length, by taking two of these equal to a certain unit base, then for the third a value can be obtained in terms of which volume can be measured, and the volume represented by a segment. Many special problems occur in connection with canals and earthwork which admit of graphical solution by means of the foregoing principles.

Addition of Segments.

Concerning addition of segments, in the sense which it is suggested that this operation should be regarded, only a few remarks need be made. The chief points to be observed is that if a movement of a point in one direction along a straight line is considered positive, movement in the opposite direction is considered negative. Also, that if A, B, C, D, &c., are collinear points, that is, points lying on a straight line, then

$$AB + BC + CD + \ldots\ldots + MN + NA = 0;$$

which is the same as saying

$$AB + BC + CD + \ldots\ldots + MN - AN = 0.$$

This rule of signs can be extended to curved lines and surfaces, and English readers will find the subject treated at length in the first chapter of Cremona's 'Graphical Calculus.'

Combination of Segments.

In the preceding paragraphs the direction of the segment has not been taken into account as a measurable quantity, although the properties of direction form the basis of certain constructions which have been mentioned. It has been shown that the process of combination by drawing equipollent (equal and parallel) segments is simple, and it need scarcely be said that the order in which the segments are taken is a matter of indifference, the resultant being the same in every case; since no matter in what order a series of movements are made the final change of position must be the same, though this is generally stated and proved formally as a sort of proposition. Cremona further gives and quotes various other propositions relating to the combination of segments which, though interesting, have little bearing upon the subject matter of the present report.

One well-known property, however, of general application requires notice.

Let A B, B C, C D, D E, . . . fig. 7, be segments, the notation denoting the direction in which they are measured. At any point O_1 in A B draw two segments, O_1a, O_1b, of such length that, in the equipollent diagram OA′B′, A′B′ becomes the resultant found by combining O_1a and O_1b. Proceed in the same way with a point O_2 in B C, which is found by producing O_1b to meet B C, the triangle O B′ C′ being the equipollent diagram. It is clear that the order of procedure might have been reversed, and any point O being first chosen the rays OA′, OB′, . . . might have been drawn, and the polygon $O_1\,O_2\,O_3$ . . . then found.

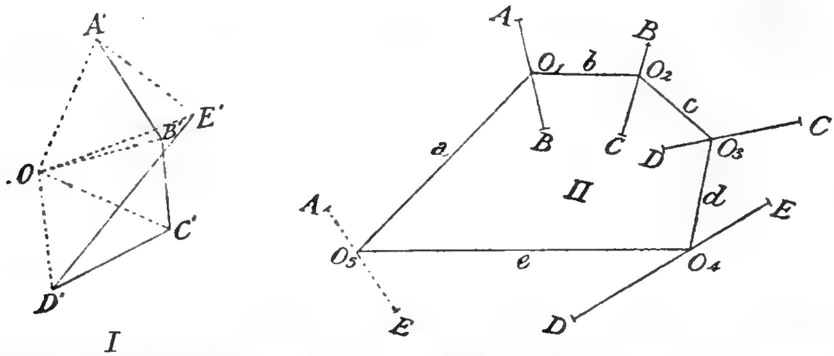
These two diagrams have the well-known relation, that for every point from which lines radiate in one there exists a corresponding closed figure in the other.

Thus to O_1	corresponds	the triangle	O A′ B′
O_2	"	"	O B′ C′
O_3	"	"	O C′ D′
. . .	"	"	. . .

If the end lines O_1a and O_4e be produced to meet at O_5, then to O corresponds the polygon $O_1\,O_2\,O_3\,O_4\,O_5$.

When the correspondence exists in two figures they are said to be reciprocal to each other, but the case given is only a special one of a more general theorem, hereafter considered. The diagram marked I. is alluded

FIG. 7.



to as the 'first derived diagram,' and that marked II. as the 'second derived diagram'—terms which might with advantage be respectively substituted for the present ones of 'force' polygon and 'cord,' 'rope,' or 'funicular' polygon, since the figures are themselves perfectly general in their applications.[1]

If the segments to be combined do not all lie in one plane, the projections on two planes must be obtained and combined in each, just as for the case of given segments in a plane; but the points from which the first lines and the derived polygon are drawn must be the projection of the same points in space. The two resultants so obtained are the projections of the true resultant of the given segments.[2] The method of projection on planes enables the properties of segments in space to be dealt with in the same way as with segments in planes. The figures so obtained are reciprocal, but they are the projection of solid bodies, the bounding planes of which intersect in the given segments, and the solids themselves are also said to be reciprocal.

In fig. 7 the point O would be the vertex of a pyramid, but cases in which there are polyhedra of other forms of every possible kind also fall under the same laws relating to reciprocal figures.

A large number of theorems have been discovered as a result of combining segments in this way. Thus, suppose two segments are to be combined, the magnitudes of which are constant, but which take every possible direction, the inclination of both making the same angles on opposite sides of the vertical. The locus of the resultant, having the fixed point for its centre, is an ellipse, the major and minor axes of which are respectively $a+b$, and $a-b$, a and b being the respective segments. If this theorem is extended to three dimensions of space the locus of the surface described by the extremity of the resultant is an ellipsoid. Rankine's ellipse and ellipsoid of stress, also the ellipse and ellipsoid of strain, follow from this proposition. Again, if the two segments are always in the same direction, and, though not constant in

[1] Professor Ritter, of Zurich, in a conversation with the writer of this report expressed his approval of the terms above suggested, and stated that they were already used in a treatise by Herr M. Nehls, Director of Waterworks, Hamburg.

[2] It is to be noted that this applies to segments as such.

length, have a constant product, the locus of one extremity of their resultant (the other extremity being at a fixed point) is an hyperbola.

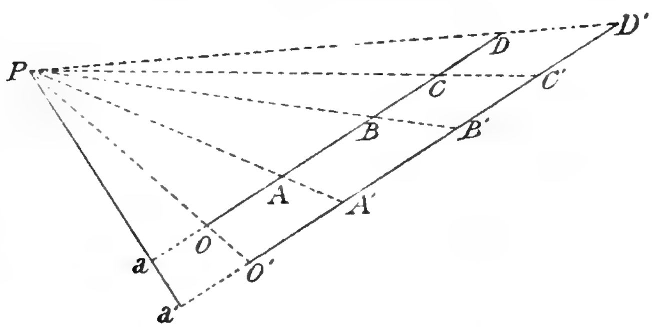
Multiplication of Segments.

The simple process by which a segment is multiplied any given number of times has been already alluded to. This is done in many ways by using the properties of similar triangles.

It is often required to multiply a number of segments by one multiplier, in which case the following constructions (in which the multiplier is taken as K) may be used, all depending upon the property of correspondence in two rows of points.

(1) Take any point O (fig. 8) and set off the segments O A, O B, O C, O D, . . . in one direction; take any other point P at a distance of unity from this line or the line produced. Draw from P a perpendicular to the direction of the line meeting it in a, and take on P a a distance P a'=K.

Fig. 8.



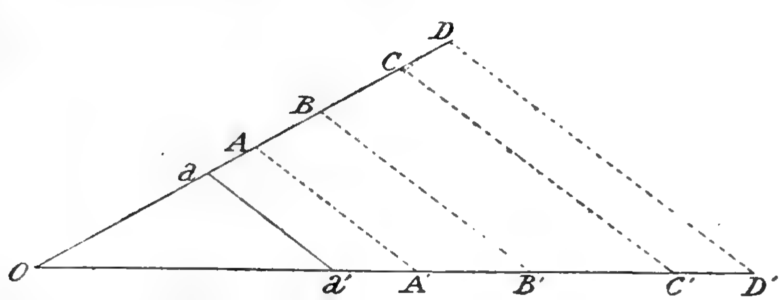
Draw through a' a straight line parallel to O D, meeting the pencil of rays P O, P A, P B, . . . in the points O′, A′, B′, . . .

Then

$$O'A' = K \cdot OA$$
$$O'B' = K \cdot OB$$
$$O'C' = K \cdot OC$$
$$\ldots = \ldots$$

(2) Now suppose the point, instead of being taken at unit distance, to be infinitely distant, the pencil of rays will be parallel. Along O D,

Fig. 9.



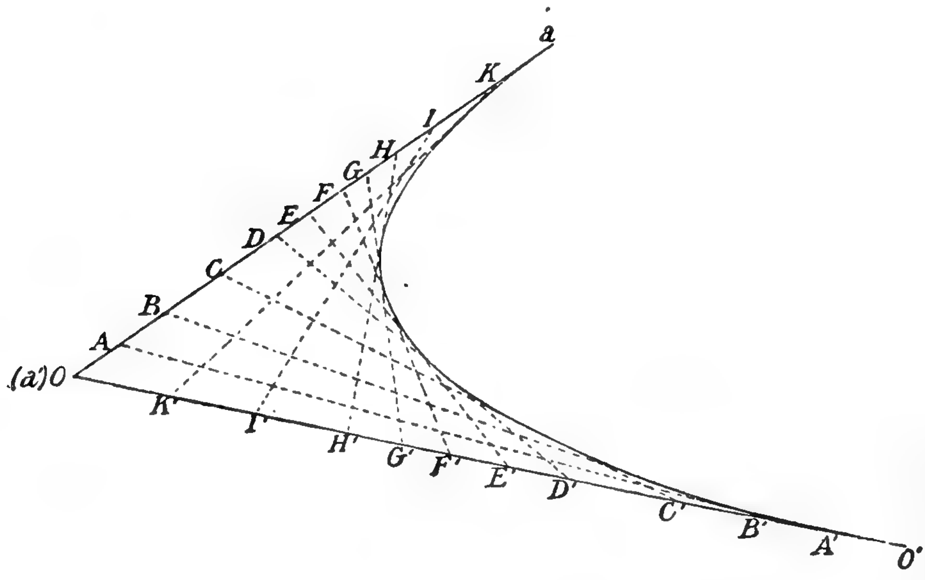
(fig. 9) take $Oa=1$, and at any angle take $Oa'=K$. Join $a\,a'$. Through A B C D . . . draw A A′, B B′, C C′, . . . parallel to $a\,a'$. Then

$$\begin{aligned} OA' &= K.OA \\ OB' &= K.OB \\ OC' &= K.OC \\ \dots &= \dots \end{aligned}$$

(3) If the two rows of points intersect in points which do not correspond, the property of the parabola may be employed.

Let O A, O B, O C, . . . (fig. 10) be given segments; take O a along the same line equal to unity (or n); at any angle to O a draw the line O O′, where $O'a'=O'O=K$ (or n K). Draw a parabola having O a and O O′ tangents at a and O′.

FIG. 10.



If A A′, B B′, C C′, . . . are tangents,

$$\begin{aligned} O'A' &= K.OA \\ O'B' &= K.OB \\ O'C' &= K.OC \\ \dots &= \dots \end{aligned}$$

The problem of successively multiplying OA by K_1, K_2, K_3, . . . is of course practically the same as the foregoing, but may be performed in four ways, mentioned by Cremona.[1]

It may be required to multiply a segment by a series of quantities successively. This may be done by various constructions, of which Cremona, Favaro, and others give several. The process in all cases simply consists in a repetition of ordinary multiplication, the construction being modified for the sake of convenience.

The quantity by which a segment may be required to be multiplied may be numerically equal to itself, in which case (which is equivalent to

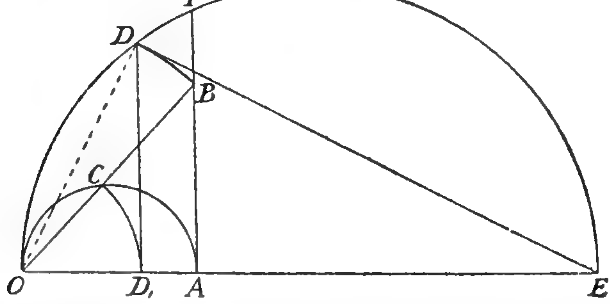
[1] P. 49 *et seq.*, English translation.

finding its square) the operation may be repeated any number of times, and any power of a quantity found. Methods of performing this operation graphically are given in various books. Reuleaux[1] gives six methods. In the first, two lines at any angle are drawn, and from their point of intersection are taken lengths equal to unity and to a on one, and equal to a on the other. Joining the extremity of unity on one, and of a on the other, and drawing through a on the first a parallel to it gives a point distant from the intersection equal to a^2, and so on. The second is a similar construction, except that the lines joining the first two are drawn perpendicular to each other. The third and fourth are practically the same. In the fifth a semicircle is drawn with diameter equal to unity, and a chord is drawn from one extremity of the diameter equal to a. From the point of intersection with the circle a perpendicular is dropped on the diameter, and the segment intercepted between this perpendicular and the end of the diameter originally used is equal to a^2. By repeating this process with a^2 instead of a, a^4 is obtained; the segment of the chord cut off by the perpendicular from the chord of length a^2 is equal to a^3. The sixth method consists in drawing two lines at right angles, setting off on one the value of unity and also of a, and along the other only the value of a; the extremities of a on one and unity on the other are then joined, and from the extremity of a on the first a parallel is drawn intersecting the other line. The vector gives a^2. This process, continued by drawing a succession of perpendiculars, gives the powers up to any required value. This construction with any initial angle gives a spiral, the right angle being a special case, and the general case is given by Cremona; Jäger has pointed out that not only do the vectors represent a geometrical progression, but also the corresponding sides of the spiral intercepted by successive vectors.

The various methods of finding roots are much the same as the foregoing, the equiangular spiral being the most useful curve for this purpose. Favaro (p. 45) treats at some length the properties of this spiral, and gives its applications. He also gives the following construction for obtaining the cube root of a segment:—

Take a semicircle upon a segment O A (fig. 11) equal to unity. Set up a perpendicular A I, and through O draw any straight line, cutting the semicircle in C and the perpendicular A I in B. With O as centre

FIG. 11.



and O C as radius, draw an arc cutting O A in D_1, and draw D_1 D perpendicular to O A, meeting in D the arc drawn through B with O as centre.

[1] *Der Konstructeur*, 4th edit., p. 87 *et seq.*

Join O D, and draw a perpendicular to it through D, cutting O A produced in E.

Then $$OD=\sqrt[3]{OE}.$$

In this way points on a curve can be found. Having obtained the curve, any cube root (say of l) can be found by setting off a length

$$OE=l.$$

Upon O E describe a semicircle intersecting the curve in D.

Then $$OD=\sqrt[3]{l}.$$

Culmann treats the subject of roots, and shows how to obtain the value of

$$x=\sqrt[3]{abc},$$

that is of $$\frac{x}{a}=\sqrt[3]{\frac{b}{a}\cdot\frac{c}{a}}.$$

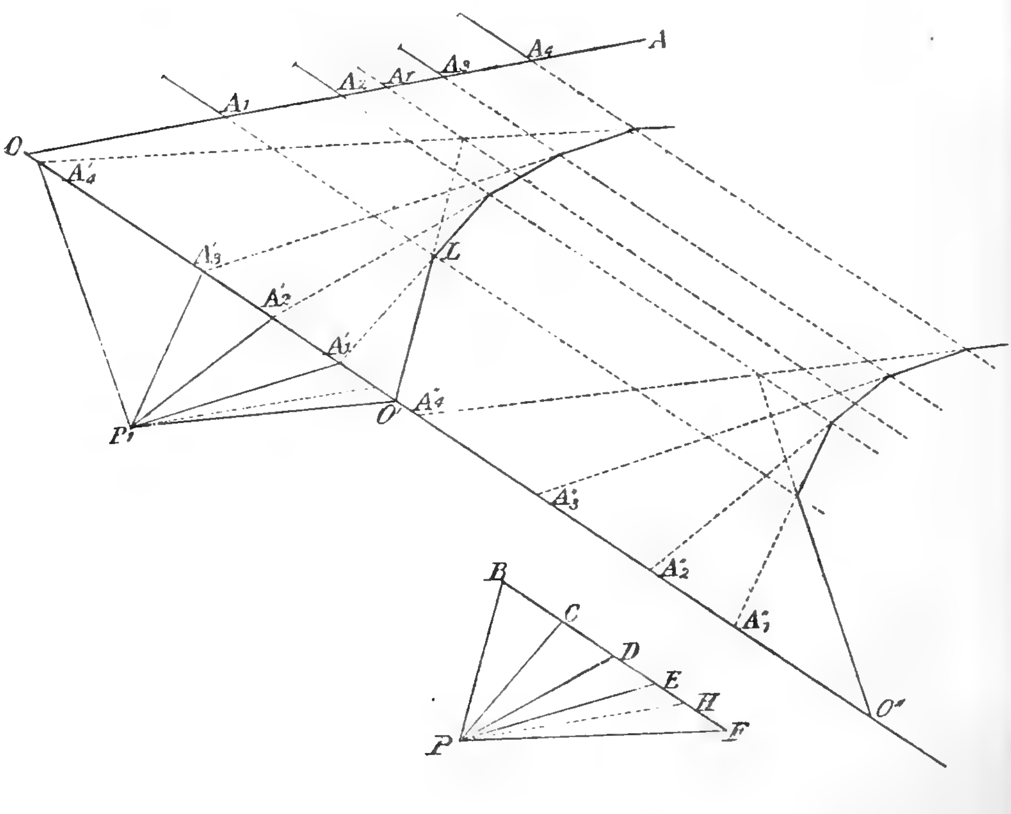
Cremona treats fully the use of the logarithmic curve in the extraction of roots, and shows how to find by its use

$$\sqrt[r]{p_1\times p_2\times p_3\times\ \ldots\ p_r}.$$

Probably the most important of all graphical constructions in relation to mechanical science is that which gives the sum of a series of products. Suppose the values required to be

$$\sum(OA\,.\,K)=OA_1\,.\,K_1+OA_2\,.\,K_2+OA_3\,.\,K_3+\ \ldots$$

FIG. 12.



Take OA_1, OA_2 (fig. 12) along the line O A, and along any other line take

$$\begin{aligned} BC &= K_1 \\ CD &= K_2 \\ DE &= K_3 \\ \ldots &= \ldots \end{aligned}$$

Take any point P at a distance of unity (P H) from B C D taken parallel to $O A_1$ . . . and join P B, P C, P D, . . .

Draw parallels to these, as shown in the figure, to meet other parallels to B C D E . . . through $A_1 A_2 A_3$ . . . Then the segment cut off by the first and last ray on the parallel through O gives the sum of the products.

The reason for this construction is obvious, since it is merely a device for obtaining the necessary similar triangles required, in such a position as to enable the products to form one continuous segment. These similar triangles are shown in dotted lines, and it is obvious that since $O' A_1' L$ and P B C are similar triangles

$$\frac{O'A_1'}{BC} = \frac{OA_1}{PH} \text{ or } \frac{O'A_1'}{K_1} = \frac{OA_1}{1},$$

that is

$$\frac{O'A_1'}{K_1} = \frac{OA_1}{1},$$

or

$$\begin{aligned} O'A_1' &= OA_1 \,.\, K_1 \\ A_1'A_2' &= OA_2 \,.\, K_2 \\ A_2'A_3' &= OA_3 \,.\, K_3 \\ \ldots &= \ldots \end{aligned}$$

Hence $$O'A_n' = \sum OA \,.\, K.$$

The figure is usually taken, so that $OA_1 A_2$ . . . is horizontal, and B C D . . . is vertical, as in this case there are many direct applications; the general nature of the proposition in which the lines are taken at any angle is, however, apparent.

This important construction appears to have been first given by Culmann. In the first edition of his work it is stated in paragraph 26, under the title 'Funicular Polygon or Line of Pressure and Force Polygon,' but in the second edition it is placed in the preliminary chapter entitled 'Operations upon Lines,' under the heading (paragraph 4) 'Summation Polygon, or Funicular Polygon,' and it forms the basis of much of graphic statics. It is there given in a very general form, which, notwithstanding the number of years that have elapsed, has not appeared in any English work; and as the style and method of Culmann are, to say the least, original, the following free translation of that article is given:—

Summation or Funicular Polygon.

After stating that in statics we often have to multiply, not only separate lines, but whole rows of lines by different ratios, and to add up these ratios as well as the products, it is stated that if we execute the summation of these products in such a way that the resulting triangles

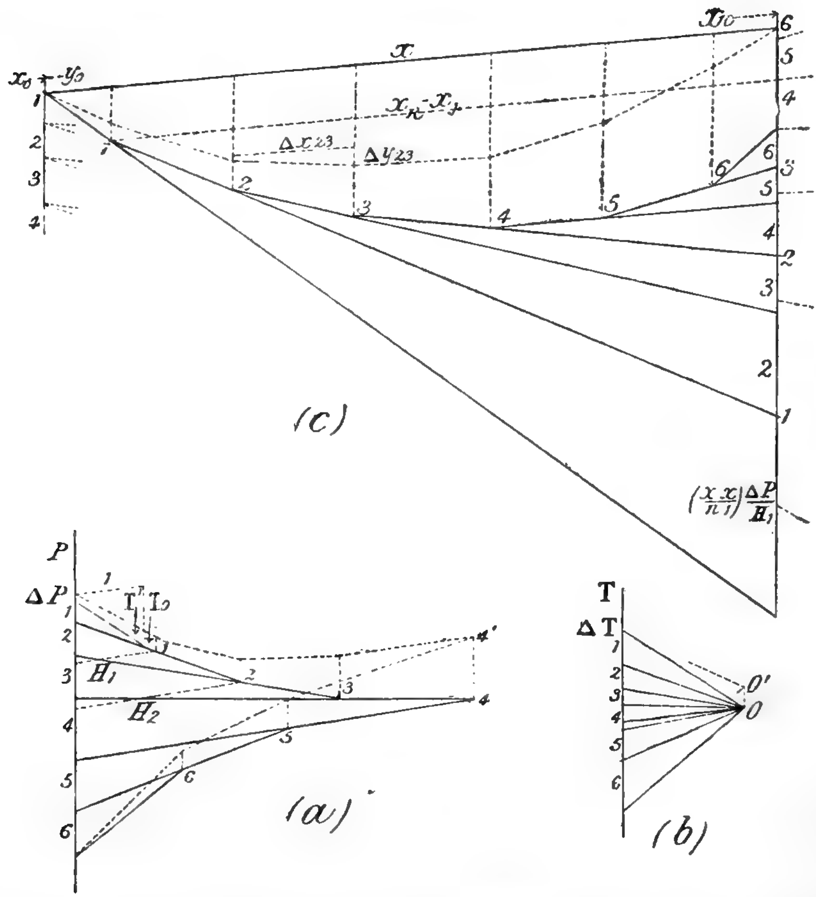
are continually connected to one another, we get the summation polygon, which, for its statical meaning, may also be called the funicular polygon, and which forms one of the most important expedients of graphical statics.

Suppose the products which have to be added together to be of the form

$$\sum_1^n x_i \frac{\Delta P_i}{H_i},$$

in which expression the x_i represent abscissæ measured from a given point in a definite direction, ΔP_i separate loads acting vertically downwards, and H_i any reduction coefficients. At present we must suppose that the ΔP as well as the H are given by straight lines. In fig. 13 *a* we set off on the vertical direction line of the ΔP all the forces, having regard to their signs, and we get on this line $P = \Sigma \Delta P$.

FIG. 13.



On this line, therefore, can also be represented the sum of any number of successive values, ΔP. Through the first extremity of ΔP_1 we draw a line with any chosen ratio of the ordinate and abscissa; through a point of this line whose distance from P measured in the direction of x is H_1, and through the other extremity of ΔP_1, we draw a line to the

point 2, whose distance from P, also measured in the direction of x, is H_2. The distance of the extremity of H_1 from the upper extremity of ΔP_1 equals $H_1 t_{01}$; therefore from the lower extremity it equals

$$H_1 t_{01} - \Delta P_1.$$

But as this equals $H_1 t_{12}$ it follows that the ratio of the ordinates and abscissa in the second case is

$$t_{12} = t_{01} - \frac{\Delta P_1}{H_1}.$$

Through the lower extremity of ΔP_2 draw a third line through the point 2, and produce it to the point 3, whose distance from the line P equals H_3. If we proceed exactly as before we get the ratio of the ordinates in the third case

$$t_{23} = t_{12} - \frac{\Delta P_2}{H_2} = t_{01} - \frac{\Delta P_1}{H_1} - \frac{\Delta P_2}{H_2}.$$

Proceeding in this way we get the polygon of the values of t, in which the ratio of the ordinates and abscissa are in any given case

$$t_{i,\,i+1} = t_{01} - \sum_1^i \frac{\Delta P_i}{H_i}.$$

We can easily see from this that t_{01} plays the part of an integration constant with regard to

$$\sum_1^i \frac{\Delta P_i}{H_i}.$$

If through any point O in fig. 13 b we draw parallels to the side of the polygon 1, 2, 3 . . . of fig. 13 a, then these cut the ratios

$$\Delta t_i = t_{i,\,i+1} - t_{i-1,\,i} = \frac{\Delta P_i}{H_i}$$

on the vertical whose distance from the chosen point O equals 1, and these ratios appear on this vertical, which we now may call the line of t, added up in the same order in which the ΔP have been arranged. If we alter the ratio of the ordinates and abscissa of the first side 01, *e.g.*, we make it t_{01}' instead of t_{01} (as shown by the dotted lines in fig. 13 a), then the whole of the figure changes, but the points on the line P remain unaltered owing to their construction, and all other points lying outside P move on vertical lines. Accordingly both figures have the straight line P and the parallel pencil of the verticals in common. But it follows from geometry of position, or even indirectly from the construction, that in such systems all corresponding rows of points lying in the same verticals are congruent; for the rays intersecting each other, say in 4, cut off on all verticals the same distances of the rays as those which intersect each other in 4′, because 4 and 4′ are equally distant from P; and as this is true for any other two rays the above proposition follows from it. Besides it must be so, for these distances can be expressed by the ratio $\frac{P_i}{H_i}$, and also by the position of the verticals, both of which are independent of t_{01}.

All that has been said about fig. 13 a relates also to fig. 13 b, the point

O moving up to O′. The abscissa, which ought to be multiplied by the new ratio, is drawn from a point x_n (fig. 13 *c*) with regard to its sign in such a way that they appear as the difference of the abscissæ $x_n - x_i$; through all the x_i we draw verticals and join constantly those verticals by parallels to the corresponding *t* of fig. 13 *b*. Starting from any point, say from 0 to 1, draw a parallel to t_{01}, from 1 to 2 a parallel to t_{12}, and so on; then these prolonged sides of the polygon cut on the vertical x_n the required products $(x_n - x_i)\,\frac{\Delta P_i}{H_i}$. Because by the similarity of figures we have for ΔP_1 and x_1

$$1,\ x_n - x_1,\ (x_n - x_1)\,\frac{\Delta P_1}{H_1} \text{ in fig. 13 } c,$$

and

$$1,\ H_1,\ \Delta P_1 \text{ in fig. 13 } a.$$

Hence

$$\frac{x_n - x_1}{H_1} = \frac{(x_n - x_1)\,\Delta P_1 \div H_1}{\Delta P_1}.$$

But as this ratio is also true for any other value of ΔP_i, then the required products $(x_n - x_i) \times \frac{\Delta P_i}{H_i}$ are intercepted on the vertical x_n at a distance x_n from the fixed point, in the same order in which they were arranged on the line P in fig. 13 *a*. Hence we may get on this line the sum of any number of following products:—

$$\sum_k^i (x_n - x_i)\,\frac{\Delta P_i}{H_i}.$$

Let us imagine the x_i, that is, the relative position of the ΔP, as constant, whilst the x_n as varying, then nothing whatever will change in the polygon of fig. 13 *c*, only the vertical x_n will take another position. If to express this generality we write x instead of x_n, we can say that any two rays of a ray pencil representing the funicular polygon (fig. 13 *c*) cut on all verticals at a distance x the sums

$$\sum (x - x_i)\,\frac{\Delta P_i}{H_i}$$

of the ΔP_i lying between these rays.

In this result nothing is changed when the sides of the polygon in fig. 13 *c* are drawn parallel to the dotted sides of figs. 13 *a*, 13 *b*, for the above partial sums are independent of the values of the first ratio. In general, all that was formerly said about figs. 13 *a* and 13 *b* relate also to fig. 13 *c*, all corresponding verticals being congruent. This relation gives us a means of drawing two polygons through given points. For instance, let 01, the first side of the polygon, pass through a point $x_o y_o$, and the last 67 through the point $x_n y_o$; then we commence by drawing a parallel line to t_{01}, and finish the polygon as above described. If, finally, the side 67 does not pass through the definite point $x_n y_o$, there is nothing to be done except to shift the row of points obtained in the vertical x_n in such a way that the point next in order to 6 coincides with the given point $x_n y_o$. This has happened on the right side of the vertical x_n, and now the side of the polygon 01 passes through the point $x_o y_o$, and the

point 01 in the vertical x_n; the side 12 passes through the intersection of 01 with x_1, and the point similarly denoted in x_n, and so on. This construction can be executed still more easily by means of the first vertical x_o; for this line does not even change its position, and all sides of the polygon are intersected by it; therefore the last side of the polygon 67 is given by the point $x_n y_o$, and by the point 67 in x_o, viz., the intersection of the first polygon with x_o; the second is given by the intersection of this side with the intersection of the corresponding side of the former, and so on. Owing to the want of space this construction is indicated only from the side 34.

Expressions are next found for the ordinates y_i. The differences of two following coordinates are denoted by $\Delta x_{i,i+1}$ and $\Delta y_{i,i+1}$, and possess two indices, for it is impossible to denote successive coordinates by continuous indices. At the same time the difference should be positive when the ordinate of the second index is the larger one.

We have therefore

$$\Delta y_{i,\, i+1} = t_{i,i+1} \Delta x_{i,i+1},$$

and hence

$$y_n = y_o + \sum_o^n t_{n,n+1} \Delta x_{n\ n+1} = y_o + \sum_o^n \left(t_{01} - \sum_o^i \frac{\Delta P_i}{H_i} \right) \Delta x_{i,i+1};$$

or

$$y_n = y_o + (x_n - x_o) t_{01} - \sum_1^n \Delta x_{i,i+1} \sum_1^i \frac{\Delta P_i}{H_i}.$$

We can get another expression for y_n if we take notice that the first chosen side of the polygon with the ordinate x_n equals $y_o + x_n t_{01}$, and that then the segment intercepted by the sides of the funicular polygon

$$= \sum_1^n (x_n - x_i) \frac{\Delta P_i}{H_i}.$$

Hence we have also

$$y_n = y_o + (x_n - x_o) t_{01} - \sum_1^n (x_n - x_i) \frac{\Delta P_i}{H_i},$$

and therefore

$$\sum_1^n \Delta x_{i,i+1} \sum_1^i \frac{\Delta P_i}{H_i} = \sum_1^n (x_n - x_i) \frac{\Delta P_i}{H_i}.$$

By putting down the second sum of the first expression we can easily see that the second expression is a partial integral of the first, viz., if we put the real differences instead of Δx we get

$$\Delta x_{12} \frac{\Delta P_i}{H_i} = (x_2 - x_1) \frac{\Delta P_1}{H_1}$$

$$\Delta x_{23} \sum_1^2 \frac{\Delta P}{H_i} = (x_3 - x_2) \left(\frac{\Delta P}{H_1} + \frac{\Delta P_2}{H_2} \right)$$

$$\Delta x_{34} \sum_1^3 \frac{\Delta P_i}{H_i} = (x_4 - x_3) \left(\frac{\Delta P_1}{H_1} + \frac{\Delta P_2}{H_2} + \frac{\Delta P_3}{H_3} \right)$$

$$\Delta x_{n-1,n} \sum_1^{n-1} \frac{\Delta P_i}{H} = (x_n - x_{n-1}) \left(\frac{\Delta P_1}{H_1} + \frac{\Delta P_2}{H_2} + \quad . \quad . \quad . + \frac{\Delta P_{n-1}}{H_{n-1}} \right).$$

The addition of these columns gives at once

$$\sum_1^n \Delta x_{i\ i+1} \sum^i \frac{\Delta P_i}{H_i} = (x_n - x_1)\frac{\Delta P_1}{H_1} + (x_n - x_2)\frac{\Delta P_2}{H_2} + \quad \cdot \ \cdot$$
$$= \sum_1^n (x_n - x_i)\frac{\Delta P_i}{H_i}.$$

The author goes on to remark that it has been often said, and specially emphasised, that the products ought to be arranged with regard to their signs, and proceeds to point out how to deal with the construction for every possible condition of signs, concluding by a remark that, exactly as fig. 13 *c* was obtained by means of fig. 13 *b*, a new polygon can be constructed from fig. 13 *c*, giving products of the form

$$\sum \frac{z_n - z_i}{h_i} \cdot \frac{x_n - x_i}{H_i} \Delta P_i;$$

or even of the form

$$\sum \frac{u_n - u_i}{h_i'} \cdot \frac{z_n - z_i}{h_i} \cdot \frac{x_n - x_i}{H_i} \cdot \Delta P_i,$$

and so on.

The method of using two diagrams, one of which is derived from the other, forms the basis of all constructions in connection with problems in mechanical science.

There are, however, methods in which they are not directly used. Thus to find the value of the expression of the form of

$$\sum A_i x^{n-i} = A_o x^n + A x^{n-1} + \quad . \ . \ . \quad + A_{n-1}x + A_n$$

the construction given by Lill for the solution of a numerical equation may be used (Cremona, chap. vi.), or that given by Egger, which is modified by Culmann, who uses the sine instead of the tangent, and is as follows. To find the value of

$$y = a_i a_2 \ . \ . \ . \ a_i p_i + a_1 a_2 \ . \ . \ . \ a_{i-1} p_{i-1} + \ . \ . \ . \ + a_1 a_2 p_2 + a_1 p_1 + p_o$$

where p_i=a given length,

a=a positive ratio $\frac{m}{n}$ of two segments m and n.

The foregoing equation may be written

$$y = \left\{ \left(\left[(a_i p_i + p_{i-1}) a_{i-1} + p_{i-2} \right] a_{i-2} + \quad . \ . \ . \quad + p_2 \right) a_2 + p_1 \right\} a_1 + p_o$$

and the quantities in brackets may be replaced by $y_{i-1} y_{i-2}$; so that

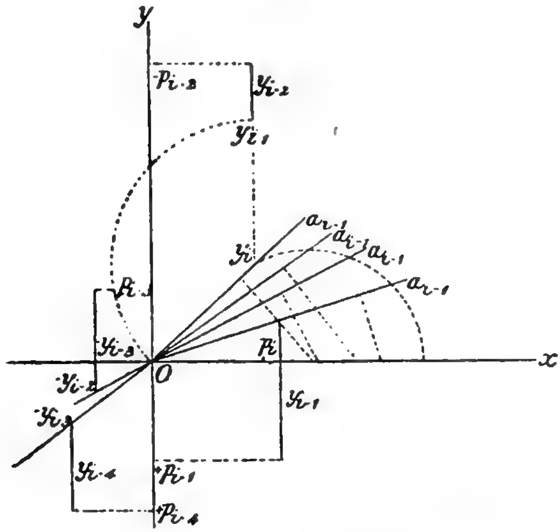
$$y_{i-1} = a_i p_i + p_{i-1}$$
$$y_{k-1} = a_k p_k + p_{k-1}$$
$$y_o = y.$$

The problem consists in finding the different values of y.

Take two axes O_x, O_y, fig. 14, and draw from the original lines at angles θ_i, θ_{i-1}, θ_{i-2}, such that

$$\sin \theta_i = a_i$$
$$\sin \theta_{i-1} = a_{i-1}$$
$$. \ . \ . = . \ . \ .$$

FIG. 14.



It is supposed that always $a<1$, and the different values of p are set off from O along the axis of y, positive *below* and negative *above*, and lines parallel to the axis of x are drawn through their extremities. If p_i is plotted off from the origin along a_i, the ordinate of the point thus obtained will be $p_i a_i$, and the vertical distance from the point from the horizontal through p_{i-1} is

$$y_{i-1}=p_i a_i+p_{i-1}.$$

This value of y_{i-1} is plotted along the ray a_{i-1}, and from point so obtained the value y_{i-1} is set off vertically *upwards*, because $a_{i-1}>1$, and also because p_{i-2} is a negative value, and it is therefore plotted above the origin. The value p_{i-2}, being already set off from O along Oy, and a horizontal drawn through its extremity, intersects the vertical line y_{i-1} produced so as to give

$$\begin{aligned} y_{i-2}&=y_{i-1}a_{i-1}+p_{i-2} \\ &=(p_i a_i+p_{i-1})a_{i-1}+p_{i-2}. \end{aligned}$$

Proceeding in this way the required value of y is obtained, which when all the values of a are the same gives

$$y=p_i a^i+p_{i-1}a^{i-1}+ \quad . \quad . \quad . \quad +p_o.$$

By making a an unknown quantity x and taking $y=0$ the equation

$$0=p_i x^i+p_{i-1}x^{i-1}+ \quad . \quad . \quad . \quad +p_o$$

can be solved, this being an equation of the nth degree with one unknown quantity.

CENTROIDS AND MOMENTS OF INERTIA (DERIVED DIAGRAMS).

The construction for finding continuous products needs further consideration, apart from the applications already mentioned, as it is a matter of general importance to have a graphical method for obtaining

the sum of a series of second products. The figure already used (fig. 12) may be employed to indicate the process. In this figure the first products have been obtained, and by taking a new pole P_1 at a distance of unity, and drawing the rays as shown, and then drawing the parallels precisely in the same way as in the first case, a number of values of the form $OA^2 . K$ are obtained, each of which is called the 'moment of inertia' of the given segment about that point,[1] so that the length of $O' A_4''$ becomes

$$\Sigma OA^2 . K = I = \text{Moment of Inertia}.$$

It may be required to obtain a series of the form

$$\Sigma\{(OA . K)O'A'\},$$

where the values of OA and $O'A'$ both change, in which case a graphical solution is also readily obtained.

The construction for continuous products enables the mean value to be found of OA (say OA_r), such that

$$OA_r = \frac{\Sigma OA . K}{\Sigma K}.$$

This is done by producing the two extreme lines in the second derived figure, which were drawn parallel to those of the first figure, until they intersect, and through the point of intersection drawing a parallel to the line B C D, and the intersection of the line with the line $OA_1 A_2 \ldots$ giving the required distance. This is shown in fig. 12. Now it does not matter what distance O is taken along the line $A_1 A_2 A_3 \ldots$; the position A_r relatively to $A_1, A_2, A_3, \ldots$ is always the same.

Now the actual position of the segments in the direction of their own length has nothing to do with the result, and wherever O is taken, so long as the perpendicular distance to the segments is unaltered, the distance $O A_r$ of the perpendicular upon the direction of the segments through O remains the same. Moreover, the sum of the products of the segments into their distances from A_r (having due regard to their sign) is zero.

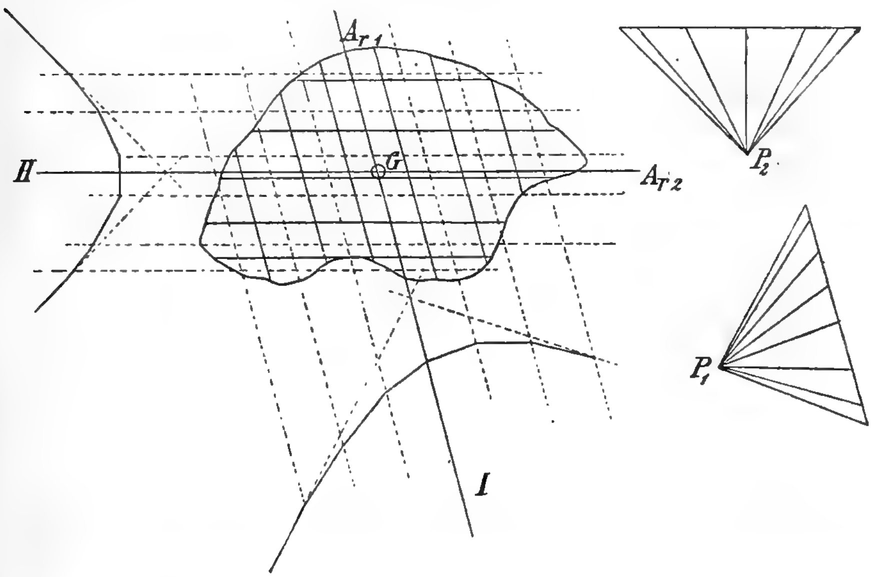
Suppose that the number of segments is infinitely great, and that they are infinitely close together, so that their extreme points form the locus of the boundary of a plane figure; then the sum of the products about any point in the line through A_{r1} (fig. 15), parallel to the direction of the segments, is zero. Next, suppose the same boundary to be formed by the extreme points of a similar second series of parallel segments, taken in some other direction. The same will hold with regard to the line through some point A_{r2} for the second series, and parallel to them. The intersection of these two lines gives a point G about which the sum of the products of every series of parallel segments whose extreme points lie on the boundary of the figure is zero. This point is called by Cremona and others the 'centroid' of the area in question, and its determination for surfaces of various kinds is a matter of great practical importance.

The way in which the matter has been approached, though not perhaps the simplest from the point of view of application in mechanics, indicates at once the graphical method of determining centroids. Thus any plane

[1] This term is quite meaningless for the most usual applications in engineering, and might be replaced by some other, as it presents a difficulty to those who have not had a mathematical training.

figure may be divided into parallel strips and segments, representing the areas drawn through the centre of each; the line containing the centroid is then found. This operation is repeated with parallels in some other direction, and the intersection of the two lines containing the centroid gives the point required.

FIG. 15.



There are numerous propositions relating to figures of different known forms given by Culmann and others, such as for the triangle, trapezium, sector of a circle, segment of a parabola, &c., but the method of derived figures enables the centroid of any plane area to be obtained.

Segments representing volumes and the centroids of solids can be found by a similar process, just in the same way as the centroid is found for a series of segments when the first products are taken.

A point A_i, corresponding to the centroid, can be found in the perpendicular from any point O when the second products are taken; but it may be remarked that

(1) The square of the distances being taken, the sum of the products about the point can never be zero.

(2) The point A_i changes for every change in distance of the point O. The determination of the distance, which is called the radius of gyration of this point from O, can be graphically obtained, and the method is explained in Culmann's work, and by Chalmers and others.

The segments have hitherto been drawn in the plane of the paper, but there is no necessity to do this; indeed, the cases which occur when segments are multiplied are usually such that one series of segments is taken as acting at right angles to the plane of the paper, their magnitude being represented by an area, so that if an area is divided into a number of equal parts the segments are equal, and equal in number to the divisions. If the segment does not act at right angles to the plane, then the intersection with the plane will give the shortest distance of the segment from it, and therefore the length of the second segment by which it is to be multiplied.

Central Ellipse and Kern.

Suppose the foregoing operation performed for a certain point O, assuming that the segments which have their extremities on the boundary of the area have a certain direction. Suppose, further, the operation repeated with the segments in various directions and the respective radii of gyration found. If these be plotted from the point O in the directions perpendicular to their respective direction, and parallels to the directions of the segments in the corresponding positions are drawn, these parallels will be found to envelop an ellipse. This ellipse is known as the 'ellipse of inertia,' and in the case when the point O is the centroid of the figure under consideration the ellipse is called the 'central' ellipse. The term 'momental' ellipse is often used for the ellipse of inertia, the central ellipse being called the 'equimomental' ellipse. The foregoing is stated as follows by M. Lévy:—'If upon different lines issuing from any point whatever, in a plane, we plot their lengths, inversely proportional to the radius of gyration relatively to these lines, the locus of the extremity of their lengths forms an ellipse.'[1]

The proof of this and other properties of the central ellipse by that writer are, with slight alterations, given in the following paragraphs, where by using the idea of segments instead of that of forces the treatment is made perfectly general.

Let $O\,x$ and $O\,y$ be axes of coordinates. Let any line $O\,u$ making any angle a with the axis of x be that about which the moment of inertia of a segment P whose point of intersection with the plane p is required.

Then

$$I_P = P\,(y \cos a - x \sin a)^2,$$

and the moment of inertia of a number of such segments becomes

$$\Sigma I_P = \Sigma P\,(y \cos a - x \sin a)^2,$$

or

$$r^2 \Sigma P = \Sigma P y^2 \cos^2 a + \Sigma P x^2 \sin^2 a - 2 \Sigma P x y \sin a \cos a\,;$$

or if

$$a_1^{\,2} \Sigma P = \Sigma P x^2$$
$$b_1^{\,2} \Sigma P = \Sigma P y^2$$
$$c_1^{\,2} \Sigma P = \Sigma P x y$$

(I)

$$r^2 = a_1^{\,2} \sin^2 a + b_1^{\,2} \cos^2 a - 2 c_1^{\,2} \sin a \cos a.$$

Take upon $O\,u$ a length

$$Om = \frac{d^2}{r},$$

where d is some constant.

Then x_1 and y_1 being the ordinates of M

$$x_1 = \frac{d^2}{r} \cos a,$$

$$y_1 = \frac{d^2}{r} \sin a,$$

[1] *La Statique graphique*, vol. i. p. 400.

Inserting these values in Equation I. we get

$$b_1^2x_1^2+a_1^2y_1^2-2c_1^2x_1y_1=d^4,$$

being an equation of the ellipse, where a_1 and b_1 are the radii of gyration relatively to the axis of x_1 and y_1, and

$$c_1^2=\frac{\Sigma P x_1 y_1}{\Sigma P}.$$

If two other axes of coordinates be taken, an equation of the form

$$b^2x^2+a^2y^2-2c^2xy=d^4$$

is obtained, a and b being the radii of gyration relatively to the new axis, and

$$c=\frac{P\,x\,y}{\Sigma P}.$$

If the axes of x and y correspond to the direction of the major and minor axes of the ellipse, for which case

$$c=0 \text{ or } \Sigma Pxy=0,$$

then

$$b^2x^2+a^2y^2=d^4;$$

or when

$$d^4=a^2b^2$$

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1.$$

In the foregoing case the moment of inertia has the same sign as the segment. If all the segments have the same sign (say +) in this case, a^2 and b^2 being positive, the curve is an ellipse. If, on the contrary, the segments have not the same sense, the moments of inertia relatively to the principal axis may be of contrary sign; that is, a^2 and b^2 may be replaced by $-a^2$ and $-b^2$; the curve may then be an hyperbola. The curve relatively to the point O in a plane is called the curve of inertia relative to this point, and will be a curve of the second degree, the axis of the curve being the principal axis of inertia. When the centroids correspond with the centre of the conic it is called the 'central conic,' and is usually an ellipse, that is, the central ellipse. Instead of taking the rectangular axes Ox and Oy, take the new axes Ox_1 and Oy_1, the latter making an angle θ with Ox.

Then

$$y=y_1 \sin\theta$$
$$x=x_1+y_1\cos\theta.$$

The above equation referred to the new axes is

$$(a^2x_1^2+2a^2\cos\theta-2c^2\sin\theta)\,x_1y_1+(a^2\cos^2\theta+b^2\sin^2\theta-2c^2\sin\theta\cos\theta)y_1^2 =d^4.$$

Then since y_1^2 is the square of the radius of gyration to the axis O y_1, let b_1 be this radius. Then, taking

$$c_1^2=\frac{\Sigma P x_1 y_1}{\Sigma P}$$

gives

$$y_1 = \frac{y}{\sin\theta} \text{ and } x_1 = x - y\frac{\cos\theta}{\sin\theta},$$

where

$$x_1 y_1 = \frac{xy}{\sin\theta} - \frac{\cos\theta}{\sin^2\theta} y^2,$$

nd

$$\frac{\Sigma P x_1 y_1}{\Sigma P} = \frac{1}{\sin\theta} \cdot \frac{\Sigma P xy}{\Sigma P} - \frac{\cos\theta}{\sin^2\theta} \cdot \frac{\Sigma P y^2}{\Sigma P},$$

or

$$c_1{}^2 = \frac{c^2}{\sin\theta} - \frac{a^2 \cos\theta}{\sin\theta},$$

or

$$a^2 \cos\theta - c^2 \sin\theta = -c_1{}^2 \sin^2\theta.$$

Hence

$$a^2 x_1{}^2 - 2\sin^2\theta c_1{}^2 x_1 y_1 + b_1{}^2 y_1{}^2 = a'^2.$$

If the axes Ox_1 and Oy_1 are two conjugate diameters of the central conic, the term $x_1 y_1$ disappears in the last equation, that is to say

$$c_1 = 0.$$

Thus the characteristic relation of the conjugate diameters is

$$\Sigma P x_1 y_1 = 0.$$

In the case of rectangular axes this relation has been shown to characterise the principal axes.

It will be noticed that in the foregoing treatment distances are plotted inversely proportional to the radii of gyration, and along the lines about which the moments of inertia are taken. M. Lévy gives another method of treating the conic of inertia, corresponding to that which has been already mentioned. He does this in the following manner. If to any line Ov parallels KK' and K_1K_1' be drawn at distances from Ov equal to the length of the radius of gyration relatively to this straight line, the conic of inertia may be defined as the envelop of the lines KK' or $K_1 K_1'$. Let Ou be the direction of any conjugate diameter to the line Ov. Let

$$OA = a'$$
$$OB = b'$$

be the lengths of the conjugate semi-diameters, corresponding to the directions of Ou and Ov, and let

$$\theta = \angle uOv.$$

In virtue of the definition of the conic, if r is the radius of gyration of the axis relatively to Ov, then

$$r = \frac{d^2}{b} = \frac{ab}{b'},$$

a and b being the semi-axes of the conics; but we also have

$$ab = a'b' \sin\theta,$$

whence

$$r = \frac{a'b' \sin\theta}{b'} = a' \sin\theta,$$

that is to say, the radius of gyration relatively to Ov is the length of the perpendicular A P dropped on this line from the extremity of its conjugate diameter: hence this tangent coincides with K K′.

Just as the property of the ellipse of stress is only a special case for a plane area of the more general property for solids of the ellipsoid of stress, so the ellipse of inertia is only the special case for a plane area of the more general property for solid bodies of the ellipsoid of inertia or 'momental' ellipsoid, the 'central' or 'equimomental' ellipsoid corresponding for a solid body to the central ellipse for a plane area.

If we suppose segments of opposite sign, it is possible to obtain an hyperboloid of inertia and central hyperboloid; but this, as Routh remarks,[1] does not occur in practice, since the moment of inertia is essentially positive, being by definition the sum of a number of squares, and it is clear that every radius vector must be real. Hence the quadric is always an ellipsoid.

The properties already referred to for the central ellipse have their counterpart for the central ellipsoid; thus at any point of a space through which segments can be drawn there are always three principal axes at right angles to one another.

The above author goes on to deal with what corresponds to the products of an infinite number of segments, explaining the method given by Bresse.[2]

Let η be the abscissa of the centroid of the given section.
Then

$$\eta\iint dxdy=\iint ydxdy.$$

Consider a cylinder with a base corresponding to the given area and its generatrices normal to the plane of the area, and having a boundary plane passing through Ox and inclined at 45° to the given plane. Let η_1 be the projection of the centroid of the cylinder on the given plane.

Volume of the elementary cylinder having as base $dxdy$ is

$$V=\eta dxdy.$$

The moment about

$$Ox=\eta^2dxdy.$$

But

$$\eta_1\iint ydxdy=\iint y^2dxdy.$$

Multiplying the corresponding sides of the last two equations, and suppressing the common factor $\iint ydxdy$, we have

$$\eta\eta_1\iint dxdy=\iint y^2dxdy\,;$$

hence

$$\eta\eta_1=\frac{\iint y^2dxdy}{\iint dxdy},$$

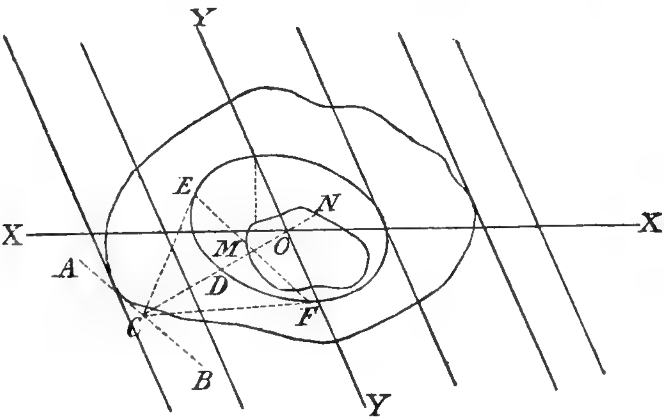
[1] *Rigid Dynamics*, 3rd edit., p. 16.

[2] *Cours de Résistance de Matériaux professé à l'Ecole des Ponts et Chaussées.*

so that the derived radius of gyration is the geometrical mean of the distances η and η_1.

The geometrical property just given may be at once applied to another very important purpose, viz., to find the mean distance from a line which, multiplied by the sum of a series of segments whose magnitude is proportional to their distance from the line in question, gives a result equal to the sum of the products of each segment into its distance from the line. This is really the problem of finding the centre of pressure in a surface over which the intensity of pressure varies uniformly, or the centre of resistance of a bent beam, the intensity of stress varying uniformly at the skin.

FIG. 16.



Let the area, fig. 16, be that of the surface in question, the distance of every point of which from the tangent A B being a measure of the segment, which has to be multiplied into that distance. The sum of the squares of the distances is the quantity required, and is thus found. Find the central ellipse of the area, and through the centre O draw the diameter O C conjugate to the diameter parallel to A B, intersecting A B in C and the ellipse in D. From C draw the tangents C E and C F. Join E F, intersecting O C in M. Take ON=OM in C O produced; then N is the required point. The point in question is the antipole of the line A B relatively to the central ellipse of the given centre.

If now for every position of the tangent A B round the given area, antipoles are found, a curve is obtained which is called—in German, *kern*; in French, *noyau*; and in English *kern*, *kernel*, *core*, and *heart*. The first of these seems the best term.

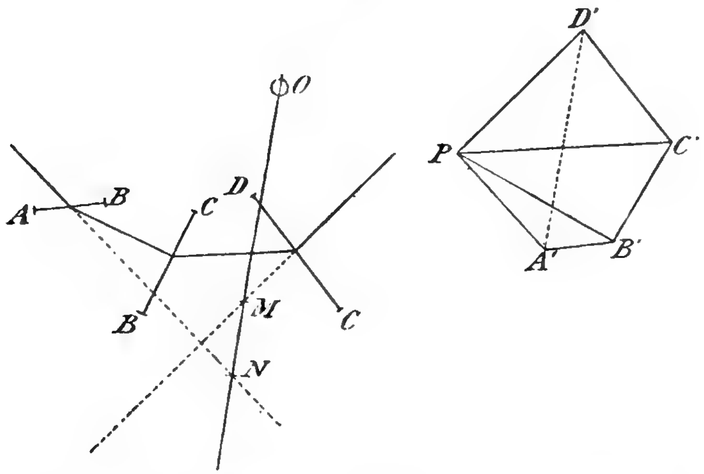
It has already been shown how the sum of a number of products may be obtained for any conditions of sign, and in certain special cases it is necessary to have a graphical statement of the result which one series of the two quantities multiplied together varies between certain limits. Bending moment diagrams, deflection curves, and moment of inertia diagrams are examples of such graphical statements.

THE SUM OF THE PRODUCTS OF NON-PARALLEL SEGMENTS.

Hitherto the products of parallel segments have been dealt with, but it may also be required to find the sum of a series of products in which the segments representing different magnitudes of the same kind have

different directions in a plane, and it may not be desirable to commence by making the segments parallel. Let A B, B C, C D, . . . (fig. 17) be segments, the sum of the products of which into the perpendicular distance of their directions from a given point O is required.

FIG. 17.



Draw the equipollent diagram by combining the segments as already explained. Take any pole P and draw the first derived diagram, and then the second derived diagram, and through the point O draw a parallel to the resultant A′ O′. Then the part of it M N intersected between the two extreme lines of the second derived diagram gives the required sum of the products.

If the point O lies in the resultant which is the line through the point of the intersection of the two extreme lines parallel to the resultant in the first derived diagram, the sum of the products is zero.

Much more might be written on such subjects as the Sum of Products in Space, the Properties of Reciprocity, and the Null or Focal System, but their treatment would require more space than can be allowed to the report in the present volume.

DIVISION II.—SUMMARY OF PROBLEMS FOR WHICH GRAPHIC SOLUTIONS HAVE BEEN PUBLISHED.

As already remarked, the limits of the report do not allow a complete statement of the solution of problems in mechanical science to be given. The following is a classified outline of the subject :—

1. FORCE IN ITS APPLICATION TO BODIES CONSIDERED AS BEING RIGID.

(1) *General Treatment of External and Internal Forces.*—Parallel forces. Centre of gravity of areas and bodies.

Bending moment and shearing force diagrams for various cases of concentrated, uniform, and travelling loads.

Loci of maximum bending moment of a beam for any given system of loads.

Internal forces and stresses in any plane.

Rankine's ellipse and ellipsoid of stress.

Ritter's treatment of internal forces and problems of maximum stress. Pressure of earth.

(2) *Framework.*—The methods of sections of Rankine, of Culmann, of Zimmermann, and of Ritter. Examples in framework in which graphical solutions have been given, including English, French, bow-string, parabolic, Schwedler, Linville, and other trusses.

Hinged girders. Graphical construction for single and double swing bridges.

Framework with redundant parts.

Cases of unfavourable loading.

Limit to which a load can be placed on a framework in order to give maximum stress in a bar.

Method of determining stress in parts of a girder.

Treatment of wind pressure. Effect of temperature.

Treatment of additional forces and secondary strains. Cost of structures from reciprocal diagrams.

(3) *Suspension Bridges.*

(4) *Arches.*—Elementary treatment of the problem.

Durand-Claye's method for finding admissible lines of pressure on the arch.

Heuser's problem applied to arch work.

Conditions of equilibrium in a pointed arch.

Transformed catenary and two-nosed catenary.

(5) *Retaining Walls and Tunnels.*—Determination of amount and direction of earth pressure.

Passive earth pressure. Earth pressure on retaining walls.

Action of pressure of earth on retaining walls.

Hyperbola of earth pressure.

Lines of action of resultant pressure on retaining walls.

Parabola of cohesion

Effect of fluid behind retaining walls.

Profile of reservoir wall.

Lines of pressure in a tunnel arch.

Cases of unsymmetrical tunnels in sidelong ground.

Spherical and conical domes of masonry.

(6) *Masonry Piers.*—General consideration. Piers of great height.

Construction for a tower of masonry and for brickwork chimneys.

2. FORCE IN ITS APPLICATION TO BODIES CONSIDERED AS BEING ELASTIC.

(1) *The Simple Beam.*—Graphical construction for moment of inertia and products of inertia.

Central ellipse and ellipse of inertia.

'Kern' or 'core' of various sections.

Cases of a beam with oblique forces.

Geometrical construction of Durand-Claye's hyperbola.

Cases of an unsymmetrical beam.

Planes of greatest and least stress in a beam.

Diagrams of moment of resistance and of shearing resistance in a beam.

(2) *Elastic Line and Curve of Deflection.*—Neutral axis. Construction of the elastic line.

Cases of a beam resting on two points of support for various forms of section.

Cases of a beam encastre at one extremity and at two extremities.

(3) *Continuous Girders.*—Construction of the elastic line of beam resting on supports.

Theorem of three moments interpreted graphically.

Unfavourable conditions of loading.

Influence of variable cross-section of frame and trusses.

Curve of maximum bending moment and shearing force in a continuous girder under concentrated loads.

(4) *Elastic Arch.*—Reactions on supports and figure of elastic arch.

Elastic arches of parabolic form.

Cases in which the reactions of the supports pass through the fixed points. Hinged archwork.

Arches encastre at two extremities. Arches encastre at one support and on rollers at the other.

Professor Eddy's method of treating the elastic arch.

Arches ribbed with stiffening truss.

Spherical and conical domes in metal.

Construction of central ellipse for the elastic arch with three hinges.

Influence of wind upon the arch.

3. MACHINES.

The graphical treatment of problems for the relative position of different parts of a machine. Zeuner's diagrams.

Construction for diagrams of effort.

Linear and radial diagrams of velocity.

Use of virtual or instantaneous centre and centrodes, and of axodes.

Relative linear and angular velocities of different links of a machine.

Graphical treatment of the dynamics of machinery.

Graphical constructions for finding the outline of different parts. Teeth of wheels.

Miscellaneous problems in connection with machines, such as—

Governors.
Flywheels.
Tension in belting.
Pressure transmitted through the spokes of wheels.
Resistance of railway trains.

4. HYDRO-MECHANICS AND NAVAL ARCHITECTURE.

Constructions for the form of jets.

Impact and reaction of the water on vanes of various forms.

Graphical constructions in connection with turbines, water-wheels, centrifugal pumps.

Metacentre and the centre of gravity of ships.

Stability curves. Graphical construction for the resistance of ships.

5. MISCELLANEOUS.

Construction for the curve of steam pressure under various conditions.

Problems in connection with heat and electricity.

Division III.—The Teaching of Graphical Methods.

The examination into the treatises and systems of dealing with graphical methods which has been necessary in the preparation of this report has revealed the great divergence in the nature of the teaching of graphic methods in engineering colleges and schools throughout the world. The writer therefore felt that some practical results might ensue if information was collected from various sources as to the nature of the teaching in different countries, such as the number of hours devoted to the subject and the kind of teaching given.

Sir E. Grey, Under-Secretary to the Foreign Office, was good enough to obtain the prospectuses of the colleges in several countries. Mr. J. Smith, H.M.'s Consul at Munich, most kindly obtained the programmes of the German schools. Professor Cremona, of Rome, and Professor Dwelshauvers-Dery, of Liège, sent also most valuable information. The prospectuses of all the American technical institutes and colleges were obtained through the kindness of Professor Ira O. Baker, of Illinois University.

From the materials so obtained an abstract has been made by the writer of the details of time-tables and other information regarding graphic statics and graphical methods in the engineering schools of Germany, Austria, Italy, Spain, Russia, Belgium, Norway and Sweden, and Switzerland, and also of most of the American colleges and technical schools. A translation has also been made of the courses of instruction in graphic statics at Braunschweig, Hanover, Liège, St. Petersburg, Milan, Brunn, Madrid, and elsewhere. The printing of all this would have extended the present report beyond the limit which could be allotted to it, and the MSS., together with the printed matter above mentioned. and numerous other documents bearing on the subject, which have been collected in the course of the preparation of the report, are therefore deposited in the office of the British Association for reference.

As a discussion of a report is not usual at meetings of the British Association, the writer, taking advantage of an invitation to read a paper at the recent International Engineering Congress in connection with the World's Fair at Chicago, brought forward the subject on that occasion. He was fortunate enough to obtain the opinions of some of the most eminent professors in engineering, including Professor W. Ritter, of Zurich. A verbatim report of the discussion, in which not only a large number of professors of engineering but also some well-known engineers took part, is deposited, with the matter already mentioned, for reference in the office of the British Association. The following is an abstract of the paper itself:—

It was shown that graphic methods might be classified in two divisions—(1) the plotting of results, and (2) the solution of problems. The former of these is rarely considered worthy of any special training, as a knowledge of it is apparently regarded as capable of being acquired

without any instruction. The solution of problems, on the other hand, has of recent years received a great deal of attention, under the title of 'Graphic Statics,' which is the most important, and indeed at present almost the only, special branch of the application of graphical construction. This branch is in many engineering schools dignified by a special course of lectures and classes, with even a special professor for the subject, while in many other schools the subject is not taught at all; and, again, the opinions held by practical men, and apparently also by professors in the engineering science, would seem to differ in a most remarkable manner as to the value of graphical methods. It is believed that this difference of opinion is apparent, and not real; and the very fact that so much attention has been devoted to the subject, in which at present there is no uniformity in the teaching or general agreement as to methods, amply justified the treatment of this subject before a congress; and it was with the hope that some authoritative expression of opinion might be obtained that it was brought forward.

The two divisions may be dealt with in order, taking first the plotting of results. This method is now universal, not only in the mechanical sciences, but in almost any case where statistics of any kind are employed, as it enables results, which would otherwise be difficult to grasp, to be at once made clear by a simple inspection. The various methods of plotting and the various instruments which have come into use for automatically recording such results were too familiar to need discussion. [A sketch of that portion of the report presented last year relating to the plotting of results was then given.] Now it appears to be the common idea that the interpolation of results, no less than the actual plotting, is a sort of intuitive process which is readily acquired and requires no sort of training; but on careful investigation the contrary is found to be the case. This was illustrated by various examples. The series of diagrams relating to the action of the crank and connecting-rod of an ordinary engine which were exhibited, and which were drawn for a meeting of an engineering society, were noticed to be in some respect novel, giving a satisfactory arrangement, so as to include four sets of diagrams, each of which includes a linear, central polar, and circumferential polar diagram of the same results. To many of those present these diagrams were no doubt perfectly familiar, but it was found that there were many practical engineers to whom, not only did the different series of diagrams have no definite meaning, but the difference between the three diagrams and the various points which are thereby brought out were obviously not easily grasped; and, moreover, from year to year, when bringing these diagrams before students, it has been found that only after considerable repetition, and after the student has constructed for himself a series of similar diagrams, is he able to deal with such problems or to grasp their general meaning.

With regard to the solution of problems the case is entirely different, for this subject receives a certain amount of attention in every engineering course of instruction. In England such instruction is given, as a rule, in most colleges incidentally when the subjects of statics, machines, or hydraulics are being dealt with, although recently in some cases special training in graphical methods is being introduced as a part of the course of engineering instruction, in several cases being given as a branch of descriptive geometry. Thus in the Science and Art Department, both under the heads of descriptive geometry and also machine

drawing, a knowledge of some of the elements of the subject is expected. On the continent of Europe, however, for many years, not only have special courses of lectures been devoted to the teaching of graphic statics as a separate branch of the subject, but there have been a large number of schools in which there are special professors of graphical statics. The reason for this difference is to be found, not altogether, as it is often supposed, in a want of appreciation on the part of English engineers or professors of graphical statics—for it was in England that the germ of such methods was first developed by Rankine, Clerk Maxwell, Fleeming Jenkin, and others—but because the system of appointing professors in the special polytechnics devoted to the allied sciences is there in vogue rather than in England, where one or two chairs of engineering are added to other chairs of the university or university college.

Now, it is instructive to note the general method of instruction indicated in the syllabuses of engineering schools, and which are even more clearly shown in the various text-books on the subject. From these it is clear that the general methods consist of giving certain rules, which may be called general graphic methods, and which apply to addition, multiplication, powers, and extraction of roots, which may be regarded as forming the introductory portion. This is followed by what may be regarded as an introduction to statics, in which special stress is laid on geometrical constructions, and the solution of many problems is given which would otherwise be worked out by analysis.

We may regard the well-known work of Culmann, 'Die graphische Statik,' as the first important treatise of the kind, in which work were collected problems of a general nature, under the title of 'Graphical Calculation,' which occupied the first three chapters, under the respective titles of 'Operations with Lines,' 'Rectification of Areas,' and the 'Rectification of Solid Bodies,' the whole occupying seventy pages. In the second edition of his work two chapters are introduced on logarithms and calculating rules, this portion occupying in the second edition 150 pages. In the second edition the preliminary portion of graphic statics, which occupied 130 pages in the first, here takes up no less than 350 pages, and is followed by 120 pages on the theory of the elements of elasticity, the author unfortunately not living to complete the work on the lines which he had planned out. One thing is particularly noteworthy, viz., the large space occupied by constructions and propositions, which may be regarded more or less of a general nature compared with the space devoted to the solution of actual examples. The same thing occurs in the lucid and valuable work of Bauschinger, 'Elemente der graphischen Statik,' in which there are sixty-two pages devoted to what may be regarded as matter of a general nature, and only thirty to the applications. In the work of M. Lévy, which is the standard work of France, although he has very much reduced in the second edition the portion of purely geometrical calculation, he occupies the whole of the first volume of between 500 and 600 pages with the 'Principles and Applications of Pure Graphic Statics.' The same general facts are derived from a study of the detailed course as set forth in the various programmes of technical schools, the general conclusions being that a great deal of the matter taught under the head of 'graphic statics' contains general principles of graphic methods of construction which might be taught apart from any applications at all; and its being so taught would be capable of its application, not only in cases of statics, but in dynamics and hydro-mechanics.

Take, as an example of this proposition, the ellipse of inertia and the central ellipse, which are only applied to force, and which are given as if they only referred to the problem of the beam. These theorems, however, have an equally important bearing on hydrostatics and rigid dynamics, the ellipsoid of inertia having the properties, for instance, of the momental ellipsoid of Cauchy, the central ellipsoid, and those of the equimomental ellipsoid of Legendre. Indeed, there is every indication of a gradual tendency towards the development of the science of graphical calculation, quite apart from that of graphic statics. Thus we find graphical constructions originally devised and given by writers (notably Rankine) as they were needed in works of mechanics. Next we have the first collection of graphical calculation, already referred to, of which there are remarkable examples in the little work of Cremona, 'Il Calcolo grafico,' in the preface of the English edition of which he acknowledges the work of Culmann. Cremona, however, goes considerably beyond that author, particularly in adding the important chapter on 'Centroids,' in which the properties of the centre of gravity are treated from a purely geometrical point of view, without any reference whatever to force. A still more recent work is that of Favaro, who, in his 'Lessons on Graphic Statics,' devoted his second volume entirely to the subject of graphical calculations.

From this it is clear that a course of instruction might be given, under the head of Graphical Methods, which might be taught in the same way as descriptive geometry, and which ought, indeed, to be worked in conjunction with that subject. This subject should deal with the constructions of such geometrical figures as are important for graphical application. It should also deal with the plotting of results and the general properties of plane curves, as far as the student is able to numerically effect measurements with it, which he can check by calculation. A student should be expected to do his work with great accuracy, and to regard the results he obtains as accurate enough to be useful in practical work, although such examples need not at the time be applied to any practical engineering problems. Thus, for instance, the propositions of projective geometry, so far as the null or focal system is concerned, and the projective properties of bodies, and of the pole and antipolar, might be taught; but a systematic treatment of the subject of projective geometry is not necessary for engineers. With regard to projective geometry, it may be said that, unless it is desired to study the higher branches of the subject, there is no necessity whatever of a treatment such as Culmann has given in his chapters on the 'projective relations between the polygon of forces and the funicular polygon' and 'the relation of a system of forces with the focal system, and with curves of the third degree,' or with the central axis of a system of forces, or colinear and reciprocal relations of the funicular or force polygon.

There appears to be no reason, therefore, why an elementary course of a general nature, specially arranged so as to include all that an ordinary engineering student requires to know of graphical methods, should not be introduced as a regular subject in engineering schools, and the following arguments may be brought forward in support of this view :—

(1) Although the time-tables of an engineering department are already full, yet it will be found that a course such as that suggested really includes much of what is taught at present in a desultory way, and such a course would obviate some of the teaching given under the heading

of 'descriptive geometry,' so that during one or two terms of a year it might be taken during the same hours as already devoted to descriptive geometry, with possibly one lecture a week, for one term, in the place of the actual lectures in the applied engineering, into which at present graphic methods are often obliged to be introduced for the want of proper preliminary training in the subject by a student. Moreover, the time now devoted in the engineering laboratory for the plotting of curves might be much better occupied in the drawing hall itself in connection with the practice of the plotting and interpolation of curves as a part of the subject of graphic methods, the data obtained from the engineering laboratory affording useful information.

(2) The time spent in such graphical work would be an excellent discipline in accurate drawing for a student, who is often inclined to regard a sketch roughly representing an idea as sufficient for practical purposes. A student should learn for himself that nothing is so easily deceived as the eye. It is quite true, as Professor Culmann says in the preface of his work, that 'the constructing engineer will give preference to geometrical solutions wherever an accuracy of results up to three decimals (one-thousandth), which can be perfectly well obtained, is sufficient, for his drawing instruments are always at hand, and drawing is his habitual expression of thought.' But such accuracy in drawing is by no means naturally or intuitively acquired, and the student requires training in a course of graphical methods before he would appreciate their value. Moreover such practice in actually performing the operations, and becoming familiar with the solution, is absolutely necessary, if it is to be expected that a student will really use these problems afterwards in his practical work, as such modifications become extremely puzzling owing to the want of a thorough acquaintance with the methods.

(3) It is not only necessary that a student should be familiar with accurate drawing, but also that he should be familiar with graphical constructions as a means of solving problems. The plan ordinarily adopted in the teaching of statics in conjunction with graphical methods themselves seems expecting too much for the capacity of an ordinary student, and the difficulty of getting a class of even intelligent students to correctly solve problems out of the beaten track may be attributed to the difficulty involved in combining these two things. In the use of ordinary geometry or analytical methods there are separate classes for algebra, analytical geometry, trigonometry, &c., and yet the ideas involved in them are no more difficult than those included in graphical constructions and methods. Graphical methods certainly, therefore, have the same claim to be considered as a separate branch of study.

The following proposition, supported by these arguments, was therefore brought forward :—'That in all engineering schools a separate course in graphical methods of construction may with advantage be introduced which shall deal with such problems as have a practical bearing on mechanical science, and which do not involve applications of any concrete subjects, such as statics and dynamics, *but which may familiarise the student, by means of examples accurately worked out by himself, with methods which he will be able to afterwards apply.*'

The course contemplated would be a very short one, not exceeding ten classes or lectures of one hour each, in the course of which various facts not generally taught to students in connection with the plotting of curves which most frequently arise in engineering practice would be

dealt with, and it may be mentioned that the proposition seemed to meet with the general approval of the members of the Congress.

With regard to teaching the principles underlying the modes of solving problems, these appear to fall under two heads: (1) The process which has been called 'Combination of Segments' may be said for brevity to consist in obtaining from segments a resultant representing two properties of the same kind as the given segments; for instance, in the case of statical problems, the magnitude, and direction of the forces. (2) The process which corresponds to multiplication, in which two unlike kinds of quantities are combined so as to form a result differing in kind from either. These practically include all the processes employed, but in applying them to different problems special teaching is necessary.

The writer is disposed to think, on subsequent consideration and from further discussion of the subject, that it may be advantageous to employ familiar examples in kinematics, statics, and dynamics in the actual working out of such problems, these being so selected that the students will be able to understand without difficulty the mechanical principles involved. The more difficult problems would be reserved until the student is engaged in studying the higher branches of applied mechanics, when he will by reason of the above teaching be familiar with the graphical principles employed. This system of employing familiar examples undoubtedly has the advantage of interesting students in the subject, and is a point of great importance in making clear the value of the methods. The proposed course would only slightly modify the details of what is at present actually taught in many engineering schools. It would, however, bring clearly before the student the methods themselves as distinguished from their applications.

He would also remark that some eminent authorities on technical education have very little belief in the separate study of graphical methods apart from geometry and machine drawing. But for those who are engaged in the actual work of engineering, especially those who have very little knowledge of mathematics but are to a certain extent acquainted with practical geometry, the writer is convinced, both from experience in teaching evening classes of artisans and also with day college students, that a clear treatment of the methods employed in graphical constructions, as applied to simple rules of arithmetic, is of the highest value.

In bringing the report to a close he would further remark that the teaching in many English schools of engineering seems to introduce as much of the practical applications of graphical methods as in any other country, and that much of the apparently different treatment of the subject in English as compared with foreign schools is due to a difference of arrangement of courses and of terminology.

On the Physical Deviations from the Normal among Children in Elementary and other Schools.—Report of the Committee, consisting of Sir DOUGLAS GALTON (*Chairman*), Dr. F. WARNER (*Secretary*), Mr. G. W. BLOXAM, Mr. E. W. BRABROOK, *and* Dr. J. G. GARSON. (*Drawn up by* Dr. FRANCIS WARNER.)

A COMMITTEE having been appointed by the International Congress of Hygiene and Demography (1891) to conduct an investigation as to the physical and mental condition of school children, and having commenced their work on lines approved by ample experience, your Committee decided to work with that committee, and the report here given has been prepared, by permission, from the facts accumulated by it. Thirty thousand children have been seen in forty-one schools, and notes were taken in 5,072 cases. It has not been possible to prepare a complete report, but an analysis has been made as to 16,094 children seen in eighteen schools. The method of procedure is as follows: All the children are seen in the three departments of the school—infants, boys, and girls. The pupils are observed as they stand in rank, usually a standard or smaller section at a time. The inspector, standing in front of each child in turn, holds a shilling for him to look at, so as to fix his eyes, and thus obtains a full face as well as a profile view of each side, noting the features separately and the cranium, the expression and muscular action of the parts of the face, the eye-movements, and other points. The trained observer can read off the points in the physiognomy of the individual features and their parts, noting the proportions and form of each.

Having inspected each child in the line as described, the children are asked to hold out their hands in front of them, and for a moment the action is done before them. The balance of head, spine, shoulders, as well as of the arms, hands, and fingers, are noted in each case. Finally the observer places his hand on the head, noting size, form, bosses, &c., and the palate is inspected in each case.

At each of these stages in the inquiry children presenting deviations from the normal in any particular are asked to stand aside. The teachers are then asked to present any exceptional or dull children not picked out by the observer.

Each selected child is re-examined individually, and described on a schedule form in which the defect or abnormal nerve-sign is verbally described. The teacher's report of the child's mental status is added. The name, age, and standard of each child are written in, and the number of children seen in each standard is recorded.

As far as possible a description is given of the general social status of the children, their nationality, and the general character of the neighbourhood.

For the purpose of preparing statistics each case verbally described in the report on the children is entered in a register, in which headings indicate the defects, the case being entered under such headings as correspond to its defects. The cases are thus presented in a tabular form, from which actuarial analysis and groupings can be accurately prepared.

As regards the standard of defect in observation of points of physiognomy or deviations from the normal, the observer should be well accus-

tomed to note size, texture of tissue, and in particular the parts of the features, and describe as abnormal absence or ill-proportioning of parts. Thus the cranium was not noted as small unless the circumference be less than 19 in. at eight years old, or $19\frac{1}{2}$ in. among older children, while the general volume is estimated by the open hand placed upon it: the forehead, its width and height; presence of a median ridge or lateral bosses; in the ear the presence of helix, antihelix, pinna, lobe, and the general convexity and character of the cutaneous covering, &c.

The most frequent deviations from the normal cranium are in size, small head being most common among girls, while over-large heads were frequently associated with bosses, and were most common among boys. Other types of heads were asymmetrical, and a few cases of hydrocephalus were found in schools.

Defects in palate may usually be described as narrow, arched or vaulted, or V-shaped, the straight alveolar processes meeting at an acute angle anteriorly.

The bony bridge of the nose is often ill-developed, flat, and wide. The mouth and palpebral fissures may be small.

The epicanthis, at the inner angle of the eye-opening, is often marked. Other defects in development are less frequently met with, including supernumerary ears, defect or absence of limbs, cleft palate, &c.

The deviations from normal development here recorded are those well known in criminal anthropology, and as common among imbeciles; but the degree of ill-proportioning in the bodily condition of school children is usually much less than in idiots.

Defects of bodily development are frequently found to be coincident with defects of brain, lowering mental status, but not necessarily so. The connecting link between defects of body and defective mental action is the coincident defect of brain, which may be known by observation of 'abnormal nerve-signs.'[1] It is the coincident observation of conditions of development and 'nerve-signs,' indicating brain action, that forms a special feature of the present investigation, and distinguishes the methods used from older physiognomical research.

Another fact co-related with defect in development is the tendency of such children—especially girls—to become thin, pale, and delicate. It is in the co-relation of abnormalities in the proportioning of parts of the body with abnormal nerve-signs, low nutrition, and mental dulness that we find a criterion of the really defective status connected with the abnormality. We describe, not only defective children, but every child presenting a visible defect.

As the 'nerve-signs' may be new to many readers a brief description of some may be given.

The face is conveniently divided into three zones, the frontal, the middle down to the lower level of the orbits, and the lower containing the nostrils and the mouth. Deviations from the normal muscular action and balance are termed 'abnormal nerve-signs': their value depends on the significance as indices of action in the nerve-centres which produce them.

Frontal Muscles overacting.—Horizontal creases on the forehead are thus produced in varying degree: the creases may be fine, producing a

[1] To this view of the question, as demonstrated by the original researches of Dr. Warner, the Committees attach great weight.

dull forehead; or coarse, producing a frown. This sign varies in degree, being least when the child is attentive and mentally engaged.

Corrugation.—Knitting of the eyebrows, drawing the eyebrows together, with vertical creases on the forehead.

Orbicularis Oculi relaxed.—There is a thin circular muscle encircling the eyelids. Its tone gives sharpness of outline to the lower lid, so that its convexity is marked. Its action is increased in laughter. When this muscle is relaxed there is fulness or bagginess under the eyes.

Eye-movements defective.—There may be wandering movements of the eyes without fixation; the child may not follow a slowly moving object with the eyes, but turn the head without any movement of the eyes.

Head-balance weak.—In the normal the head is held erect; it may fall forward or be inclined to one shoulder.

The normal posture of the hand when held out to the word of command is straight, all parts and the fingers being in the same plane, and the hand on a level with the shoulder, the arms being parallel.

Hand-balance nervous.—The wrist drooping, the palm slightly contracted laterally, the thumb and fingers extended backwards at their junction with the palm of the hand.

Hand-balance weak.—In this type of balance the wrist is slightly drooped, the palm contracted laterally, and the digits are slightly bent or flexed. This posture is seen in sleep when the forearm is passively held out.

Finger-twitches.—These may be seen when the hand is held out and the fingers are spread. The twitching movements may be lateral or in flexion and extension.

Lordosis.—When the hands are held out an altered balance of the spine may be seen in a weak child with arching forward in the lumbar region, while the upper part of the trunk is thrown back.

Other Nerve-signs.—This group includes the signs less frequently seen, such as the following:—Slowness of response in movement, defects of speech, over-smiling or grinning, drooped jaw with open mouth, nystagmus, paralysis, &c.

Analysis of Dr. Francis Warner's observations of 50,000 children seen 1890–92 has afforded much new information as to conditions bearing on the mental status and well-being of school children.

It has been shown that more boys than girls are ill-developed; but of such cases the girls tend more to delicacy and mental dulness, suggesting that, while the average girls may work hard with advantage, there are a certain number who need special care.

The group of children who appeared to require special training included the epileptic, imbeciles, those 'feebly gifted mentally,' and the paralysed: they amounted to 16 per 1,000. It is satisfactory to know that the School Boards of London, Birmingham, and Leicester have made special arrangements for the care of such cases. The same scientific principles as enabled their numbers to be ascertained may be used to indicate their special requirements in training.

Tracing the group of children with defects in development through certain schools, it is evident that they are more numerous in Poor-law schools and in certified industrial schools than in day schools, and that though they become fatter in resident institutions they there present more nerve disorder and more mental dulness.

Children with a defect in development form the largest class of cases noted in every group of schools, and such form of defectiveness is largely associated with nerve disorder and mental dulness. It is, however, noteworthy that a considerable proportion escape the two later evils.

Of the development cases . . .	52	per cent.	present nerve-signs.
" " "	39	"	were reported as dull.
" " " with nerve-signs	43	"	" " "

Under conditions of less favourable training the proportion of development cases with nerve-signs and the proportion who are dull rises. It seems, then, that efficient training and education do much good in preventing evils from arising in such cases.

Comparing 10,000 children in elementary day schools of upper or middle social class with 26,000 in poorer day schools, we have found in the latter a smaller proportion with defect in development, nerve disorder, low nutrition, or mental dulness.

The thin, pale, delicate children—4 per cent. of the children seen—were almost entirely confined to the class 'development cases.' Could we remove these defects we should probably have a smaller proportion of children thin and delicate as well as fewer with nerve disorder and mental dulness.

Among children with defect of the body those with 'small heads' form an important group of 2 per cent. of the children seen; the condition falls mostly upon girls, and was found unequally distributed, rising for girls in Strand to 7 per cent., in City 6 per cent., falling in Bermondsey to 3 per cent., and in certified industrial schools for girls rising to 6 per cent. Such cases were more common among the English than the Irish or Jew children.

Cases presenting some defect were least frequent among the children in the Jew free schools of Whitechapel, and most frequent among the Irish schools, as seen.

Eye cases were very frequent in all schools: many needed spectacles who did not use them, and ophthalmia and its results were prevalent in many instances.

The children reported by the teachers as dull in school were 7 per cent. of those seen, and 40 per cent. of the children presenting some defect that was described in the schedules. The greater the number of defects seen in the groups of children, the higher rises the percentage of mental dulness.

After inspecting a school and tabulating the results of observation it is easy to prepare a report comparing the child-material seen with the average, showing the effects of training the brain and the mental powers of the pupils.

The evidence accumulated tends to show that, while general education has effected excellent results, much remains to be improved concerning the care of the mental and physical conditions of children, especially as to conditions of unevolved brain power, which are remediable by better classification and training in certain cases.

This inquiry is directed to obtaining a definite statement of existing physical and mental conditions by observation of 100,000 children, and the causation of such weakness and defects as are more common among them, and the means of removing such defects which lead to ill-health and mental dulness. A methodical arrangement of investigation and

tabulation of observations is in use, and has been amply approved by experience; the elaboration of results will be submitted to professional actuarial investigation. Such a statement of facts based upon a wide range of observation will show the groups of children that need special care, and suggest the directions in which care is needed for improving the condition of the child-population. The full report which the Committee hope to publish will present a census of the physical and mental conditions of children which has not previously been obtained, and which was not possible till the modern advancements of cerebral physiology indicated the means to be employed.

The Committee desire reappointment, and suggest that the title should be altered to the following: 'To co-operate with the Committee appointed by the International Congress of Hygiene and Demography in the Investigation of the Mental and Physical Conditions of Children.'

A brief statistical report is given below (Table I.) of 16,094 children seen in eighteen schools, showing numbers of children presenting each defect and numbers in certain groups as indicated :—

TABLE I.—*Statistical Summary of* 16,094 *Children seen, showing Numbers presenting each Defect and Numbers in certain Groups.*

Defect or Group of Children	Boys	Girls
Cranial abnormality	254	230
External ears	108	36
Epicanthis	97	66
Palate	121	83
Nasal bones	39	48
'Other defects in development,' including as below	70	67
AS ABNORMAL NERVE-SIGNS:		
General balance	25	47
Expression	50	68
Frontals overacting	207	39
Corrugation	8	3
Orbicularis oculi relaxed	112	101
Eye-movements	119	83
Head-balance	28	85
Hand-balance weak	261	167
Hand-balance nervous	72	112
Finger-twitches	32	41
Lordosis	14	35
'Other nerve-signs'	142	96
GROUPS OF CASES:		
Eye cases	212	191
Nutrition low, pale, thin, delicate	184	220
Mentally dull in school	646	521
'Exceptional pupils,' including as below	63	57
Children maimed or paralysed	36	35
Children with history of 'fits' during school life	16	18
Imbeciles and idiots	3	2
Children mentally exceptional	1	3
Children 'feebly gifted mentally'	33	35

TABLE II.—*General Statistical Summary of the 50,000 Cases seen, 1890–92.—General Analysis.*

		1	2	3	4	5	6	7
—		No. of Children seen	No. of Children noted	Cases with defect in development	Cases presenting abnormal nerve-signs	Delicate, pale, or thin (Nutrition low)	Reported by teachers as mentally dull	Eye cases: Squints, &c., not Ophthalmia
		B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.
I.–XIX. Poor-law District and Separate Schools. Totals	B.	5884	1332	888	889	236	510	205
	G.	3947	685	475	388	93	281	112
	T.	9831	2017	1363	1277	329	791	317
XX.–XXVIII. Certified Industrial Schools. Totals	B.	1588	500	329	332	41	223	54
	G.	407	91	62	57	28	47	20
	T.	1995	591	391	389	69	270	74
XXIX.–XXXIV. Homes and Orphanages. Totals	B.	774	172	107	112	14	68	28
	G.	1049	186	134	112	35	113	27
	T.	1823	358	241	224	49	181	55
I.–XXXIV. TOTAL OF INSTITUTIONS AT WHICH CHILDREN ARE BOARDED	B.	8246	1994	1324	1333	291	801	287
	G.	5403	962	671	557	156	441	159
	T	13,649	2956	1995	1890	447	1242	446
XXXV.—C. Public Elementary and Day Schools. Totals	B.	18,137	3462	2213	2021	707	1387	531
	G.	16,854	2492	1491	1406	781	973	453
	T.	34,991	5954	3704	3427	1488	2360	984
CI.–CVI. Other Schools. Totals	B.	501	113	79	59	32	28	18
	G.	886	153	73	111	36	49	25
	T.	1387	266	152	170	68	77	43
I.–CVI. GRAND TOTAL OF ALL THE 106 SCHOOLS	B.	26,884	5579	3616	3413	1030	2216	836
	G.	23,143	3607	2235	2074	973	1463	637
	T.	50,027	9186	5851	5487	2003	3679	1473

TABLE III.—*General Statistical Summary of the 50,000 Cases seen, 1890–92.—Further Analysis.*

—		Analysis of Conditions of defect in development					Analysis of defective Nerve-signs											
		8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		Cranial abnormality	Palate defective	External Ears defective	Epicanthis	Other defect in development	General balance bad	Expression defective	Frontals overact	Corrugation	Orbicularis Oculi relaxed	Eye-movements defective	Head-balance weak	Hand-balance nervous	Hand-balance weak	Finger-twitches	Lordosis	Other nerve-signs
		B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.	B. G. T.
I.—XIX. Poor-law Schools Totals	B.	387	216	257	124	254	74	259	423	38	121	120	66	93	189	80	36	144
	G.	171	143	81	101	160	32	146	107	4	66	75	47	55	66	25	45	71
	T.	558	359	338	225	414	106	405	530	42	187	195	113	148	255	105	81	215
XX.—XXVIII. Certified Industrial Schools Totals	B.	160	67	106	28	122	12	56	175	28	30	87	13	35	49	25	14	34
	G.	40	18	3	3	21	6	21	14	5	5	11	8	5	14	3	4	13
	T.	200	85	109	31	143	18	77	189	33	35	98	21	40	63	28	18	47
XXIX.—XXXIV. Homes and Orphanages Totals	B.	34	32	41	14	27	0	17	43	4	12	37	1	2	47	2	2	8
	G.	79	30	9	18	38	1	31	28	6	10	32	2	9	41	8	6	13
	T.	113	62	50	32	65	1	48	71	10	22	69	3	11	88	10	8	21
I.—XXXIV. TOTAL OF INSTITUTIONS AT WHICH CHILDREN ARE BOARDED	B.	581	315	404	166	403	86	332	641	70	163	244	80	130	285	107	52	186
	G.	290	191	93	122	219	39	198	149	15	81	118	57	69	121	36	55	97
	T.	871	506	497	288	622	125	530	790	85	244	362	137	199	406	143	107	283
XXXV.—C. Public Elementary Totals	B.	910	448	621	338	483	110	344	659	123	351	547	136	404	427	319	124	237
	G.	734	332	158	248	400	123	254	132	23	243	329	245	415	358	214	202	131
	T.	1644	780	779	586	883	233	598	791	146	594	876	381	819	785	533	326	368
CI.—CVI. Other Schools Totals	B.	37	33	22	10	22	5	18	22	6	8	7	3	16	3	19	8	11
	G.	24	12	17	14	26	11	22	13	2	19	38	17	32	25	11	22	6
	T.	61	45	39	24	48	16	40	35	8	27	45	20	48	28	30	30	17
I.—CVI. GRAND TOTAL OF ALL THE 106 SCHOOLS	B.	1528	796	1047	514	908	201	694	1322	199	522	798	219	550	715	445	184	434
	G.	1048	535	268	384	645	173	474	294	40	343	485	319	516	504	261	279	234
	T.	2576	1331	1315	898	1553	374	1168	1616	239	865	1283	538	1066	1219	706	463	668

FRANCIS WARNER.

Ethnographical Survey of the United Kingdom.—First Report of the Committee, consisting of Mr. FRANCIS GALTON (*Chairman*), Dr. J. G. GARSON, Professor A. C. HADDON, Dr. JOSEPH ANDERSON, Mr. E. W. BRABROOK (*Secretary*), Mr. J. ROMILLY ALLEN, Professor D. J. CUNNINGHAM, Professor BOYD DAWKINS, Professor R. MELDOLA, General PITT-RIVERS, and Mr. E. G. RAVENSTEIN. (*Drawn up by the Secretary.*)

THE Committee have requested the following gentlemen (not members of the Association) to join them :—

Dr. C. R. Browne (representing, with Professor Cunningham and Professor Haddon, the Royal Irish Academy, and forming a sub-committee for Ireland).

Mr. Edward Clodd, Mr. G. L. Gomme (President of the Folklore Society), and Mr. Joseph Jacobs (representing the Folklore Society).

Mr. E. Sidney Hartland, Mr. Edward Laws, the Ven. Archdeacon Thomas, and Mr. S. W. Williams (representing, with Professor Boyd Dawkins and Mr. Romilly Allen, the Cambrian Archæological Association), and Professor John Rhys (forming a sub-committee for Wales).

Mr. C. M. Kennedy, C.B. (representing, with Mr. Ravenstein, the Royal Statistical Society).

Mr. H. S. Milman and Mr. George Payne (representing, with General Pitt-Rivers, the Society of Antiquaries), and a representative of the Dialect Society.

The Chairman and Secretary of the Committee, with Dr. Garson, represent the Anthropological Institute. The Committee as thus formed will consist of delegates of various learned bodies specially interested in the work, with the addition of the Chairman of the Corresponding Societies Committee.

The Committee propose to record for certain typical villages, parishes, or places, and their vicinity—

(1) Physical types of the inhabitants;
(2) Current traditions and beliefs;
(3) Peculiarities of dialect;
(4) Monuments and other remains of ancient culture; and
(5) Historical evidence as to continuity of race.

As a first step the Committee desire to form a list of such places in the United Kingdom as appear especially to deserve ethnographic study, out of which a selection may afterwards be made for the survey. The places which appear to them most suitable for entry on the list are such as contain not less than 100 adults, the large majority of whose forefathers have lived there so far back as can be traced, and of whom the desired physical measurements, with photographs, might be obtained.

The Committee addressed to persons whom they believed to be eminently capable of affording help in this preliminary search a request that they would do so by furnishing the names of such places, with a brief account of their several characteristics, mentioning at the same time the addresses of such of their residents as would be likely to support the Committee in pursuing the inquiry.

The editors of the 'Times,' 'Nature,' the 'Academy,' the 'Athenæum,'

and the 'Daily Graphic' were so good as to make an appeal to their readers to assist the Committee in the same way.

The Committee have to thank a great number of distinguished persons for their kindness in complying with this request.

The following tables show the villages and places thus far suggested in each county, the counties being arranged from North to South, with the comments made thereon by the correspondents of the Committee :—

ENGLAND.

NORTHUMBERLAND.

No villages have been suggested in this county.

CUMBERLAND.

Places	By whom suggested
Keswick	Mr. Richard S. Ferguson, F.S.A.
Penrith	Mr. William Wilson.
Cockermouth	" "
Hesket New Market	" "
Ambleside	" "
Hawkshead	" "
Aspatria	Mr. Ferguson.
Dalston	"
Orton	"
Alston	"
Allonby	"
Bromfield	"
Wastdale	"
Gosforth	"
Eskdale	"
Brampton	"
Lanercost	"
Maughanby	Mr. Jared Turnbull.
Ivegill	Dr. Barnes.
Caldbeck	"

Mr. Ferguson states that Keswick itself swarms with lodging-house keepers, foreign to the district, but the valleys radiating therefrom are aboriginal, except for an interesting German strain from German miners imported *tempore* Eliz. to work gold mines. Mr. J. Fisher Crosthwaite, F.S.A., has written upon the German strain, which is a most interesting one; the inheritors of the German blood being men of intellectual power.

Mr. Wilson, of the Keswick Hotel, suggests that the native population of the dales in lake districts might be met with at such gatherings as the hiring fairs, market days, and horse fairs in the towns. Many of the inhabitants are undoubtedly descendants of the Northmen, who formerly colonised the district, though the population, here as elsewhere, is thoroughly blended. The lake country is poor in traditions, but there are a few, such as the defeat of King Dunmail by Malcolm, King of Scotland, at Dunmail Raise, where the former was slain, and a pile of stones placed over his body. The dialect of Cumberland is best illustrated by its songs and ballads, which are numerous. The vernacular on the Cumberland side of Dunmail Raise varies considerably from that made use of on the other side in Westmorland. The Saxons are said to have colonised Westmorland, but did not settle in large numbers in Cumberland, which was mostly occupied by Danes. There are numbers

of prehistoric remains, such as a stone circle, several ancient forts, and a British village; also some Roman remains. The history of the family of Holmes of Mardale has been traced to the year 1060, when their ancestor, John Holme, came from Norway and settled there.

Aspatria, with a coal-mining and agricultural population, is a large parish in central Cumberland, and the outlying hamlets are aboriginal. Dalston is a large agricultural and manufacturing village, with similar hamlets.

Orton, an agricultural village near Carlisle, is a very primitive place, surrounded by a hedge as a protection against moss troopers, and having the fields all laid out on a plan which is the survival of an early village community.

Alston is a very secluded district of lead miners, tall in limb, very fair, due, it is said, to a German strain of miners in the fourteenth century.

Mr. Ferguson remarks that the west of Cumberland is permeated with Irish miners, at the hæmatite mines, but Allonby remains a most primitive community, largely Quaker. Bromfield is agricultural, with some mining. Wastdale and Eskdale furnish fine specimens of unadulterated Norsemen. Brampton is agricultural and mining; Lanercost agricultural.

The parish of Addingham, in which Mr. Turnbull lives, consists of four townships, Gamblesby, Glassonby, Hunsonby, and Little Salkeld. In the three last named the old type of resident yeomen is fast dying out. Gamblesby is situated at the base of Fiend's Fall: the population is a little under 300, and the people are, for the most part, living on their own estates.

WESTMORLAND.

Places	By whom suggested
Appleby	Mr. Ferguson.
Ravenstonedale	Canon Mathews.
Ashby	" "
Orton	" "
Swaledale	The Rev. J. Wharton.
Troutbeck	Mr. Ferguson.
Kentmere	" "
Lakeland generally	" "

Appleby and the neighbouring villages are described as aboriginal and sleepy hollows. In the villages named by Canon Mathews the inhabitants have been notoriously *adscripti glebæ*. At Ravenstonedale are some of the most extensive remains of great works in the remote past, and the population and dialect are exceptional. The whole parish of Orton is a complete treasury of ancient civilisations and early wars. At Swaledale the dialect and mode of enumeration are peculiar, and have been hitherto classed vaguely as ancient British. A glossary of Swaledale words was published by the English Dialect Society in 1873. The superstitions of the county point to fire worship and an oriental origin (in Mr. Wharton's opinion) quite as much as to a Scandinavian source. He thinks the original race must have been orientals, dark-complexioned, and diminutive (as suggested by Professor Boyd Dawkins), and that they fled to the mountains before the advance of a stronger people, these latter even belonging to a prehistoric period. While in counties of more level physical character, richer soil, larger population, and greater agricultural

and commercial activity traces of the past are rapidly obliterated, in the lonely valleys, on the wide moors, and among the mountains of Westmorland and Cumberland primeval traditions, dialectic data (as, for example, the use of the digamma, a sounded but unwritten power), ancient monuments and vestiges of a long-forgotten civilisation are unmistakable tokens of the former prevalence of almost vanished races.

Troutbeck is a primitive Westmorland village. George Browne, Esq., the fifth squire of the name in direct succession, is the representative of an ancient 'statesman' family, and possesses a large collection of MSS. relating to the county and valley which have been reported on by the Historical MSS. Commission.

YORKSHIRE.

Places	By whom suggested
Middleton-in-Teesdale	Dr. Beddoe.
Ingleton	,,
Clapham-in-Craven	,,
Howarth	,,
Flamborough	,,
New Forest, Richmondshire	Mrs. Gutch.
Hallgate	,,
Askingarthdale	,,
Lastingham (Pickering)	,,
Staithes-in-Cleveland	Dr. Beddoe.
Ugthorpe	Mrs. Gutch.
Hetton-le-Hole	Canon Isaac Taylor.
Havenby	,, ,,
Newton-upon-Rawcliffe	Mr. Mark Hill.
Wetwang	Mrs. Gutch.
Newton-on-Ouse	,,
Malton	Mr. Matthew B. Slater.
Idle	Dr. J. Wright.

Mrs. Gutch remarks that in the district of New Forest there must be hamlets as unsophisticated as any that Yorkshire can show. Her father's family were established there for centuries, and she visited it in her childhood; but her people are scattered, and she has not had more than a glimpse of it for well nigh forty years. It seemed at the 'back o' beyont,' and she should think change itself would find some difficulty in getting there.

At Lastingham, Dr. Sydney Ringer says, are two Roman camps and some tumuli. Not far is an old Saxon sun-dial of the time of Edward the Confessor. The inhabitants are Yorkshire dalesmen, with many of their old customs remaining.

Staithes is a fishing village, where the folk are notorious for intermarriages and for their conservation of old customs. Much in the same case were the people of Robin Hood's Bay, near Whitby, when White 'walked' there in 1858. A writer to the 'Times' in 1885 said that there was a village not more than a mile or two from Staithes 'whose inhabitants are nearly all Romanists.' This is probably Ugthorpe, one of the most secluded places in the neighbourhood, so 'far from the madding crowd' that the Reformation seems never to have touched it. The like might be asserted, says Mrs. Gutch, of more than one obscure place in Yorkshire. It used to be true of Ovington, twelve miles from Darlington, on the southern banks of the Tees.

Canon Atkinson, Vicar of Danby, suggests that by villages should be

understood parochial districts, such as his own parish, where there is no village in the ordinary sense that is a century old. Probably about the fifteenth century the inhabitants began to migrate from the centres in which they had been grouped, and to scatter themselves in comparatively isolated dwellings; but still they were the same folk, and their descendants continued to dwell in the land, and were conservative to a degree until not very long ago.

Mr. Mark Hill states that the people of Newton-upon-Rawcliffe, Pickering, with whose customs and dialect that gentleman has a familiar, extensive, and varied acquaintance, are extremely illiterate, untravelled, and behind times.

Canon Isaac Taylor remarks on the general question that the whole population was cleared off in the devastation of the north by William I., after which a mixed population slowly filtered back. Even later there have been great shiftings. In Settrington (of which parish Canon Taylor is rector) there is a nominal list of the inhabitants in 1598. All the families but two have shifted. In the West Riding there is a fourteenth-century poll-book, which would make it easy to trace continuous residence; but no earlier ethnological results would be possible, as William cleared off every soul in Wensleydale. This poll-book affords abundant evidence of large recent fourteenth-century migrations.

LANCASHIRE.

Places	By whom suggested
Torver	Mr. H. Swainson Cowper.
Hamlets, near Rochdale	Mr. J. Reginald Ashworth.
Chipping	Mr. H. T. Crofton.
Leck	" "
Blackley	Mr. James D. Wilde.
Ribblesdale	Mr. Eli Sowerbutts.
Other villages in South Lancashire	Mr. E. W. Cox.

Torver is a village at the foot of the fells, west of Coniston lake, having a rural population similar to the Westmorland villages, but lying in more open country, and with good approach from the sea at the mouth of the Duddon.

In the district of Rochdale there are a number of small hamlets which cling to old habits, and are to a considerable extent untouched by modern influences. A Flemish colony there is said to have introduced among other things the Lancashire 'clog.'

Mr. Sowerbutts remarks that almost every old village in Lancashire has a separate dialect. In South Lancashire the types of the country people will have to be found in towns. In his own district of Ribblesdale he can find a dozen people of the same type distinguished by a peculiar inflexion of the voice; but there are not many of the families left about Balderstone, such as Fenton, Ellams (or Helm), Harrison, and Coupe. He meets them daily in Manchester. His own family lived in Balderstone from time immemorial (Sowing in Butts is the derivation of the name); and wherever the name is (Lancashire, Yorkshire, Hampshire, Bremen, Mexico, the United States of America) they all come from the Ribble valley. But all are cleared out now to the towns, except a gamekeeper or two. When a lad ten or twelve years old he could go from farmhouse to farmhouse for nearly twenty miles. All are gone now. 'Eli o' Tummas o' Ruchat o' Willym o' Tummas o' Willym o' Shandy-

forth' is the method he had to use to tell who he was. That would go back about 150 years.

Blackley is a large parish, which has recently been absorbed in Manchester, and is consequently rapidly losing its individuality. About half of the parish has belonged geographically to Manchester for several years, but the rest has been cut off by a valley called Boggart Hole Clough, to which several traditions are attached, recorded in Roby's 'Traditions of Lancashire' and Bamford's 'Walk.' This portion has been until very recently a remarkably isolated and self-contained place, although within hearing of the Manchester town-hall clock. Many of the inhabitants have lived for generations in the place. One family traces its pedigree to John of Gaunt, and claims kindred with Hugh Oldham, Bishop of Exeter in 1515. The dialect of Blackley is akin to that of Middleton and Rhodes, approaching that of Rochdale, but differing from Oldham. There are no monuments or other remains of ancient culture.

Lincolnshire.

Places	By whom suggested
Isle of Axholme	Dr. Beddoe.

In north-east Lincolnshire there is a Danish element.

In the village of Denton there is a curious sort of tribe-family of the Scoffields, the result, it is supposed, of a long sequence of marrying among themselves. When Lady Welby came to live there there were sixteen families of the name, now reduced to twelve.

Derby.

Places	By whom suggested
Edale	Mr. H. T. Crofton.
Castleton	" "
Lullington	Rev. R. H. Clutterbuck, F.S.A.

In Lullington, near Burton-on-Trent, Mr. Clutterbuck was formerly curate, and was struck by the association of a few families; there were but about three or four family names (Coates, Welton, and Arsbrook) that really belonged to the place.

Cheshire.

Places	By whom suggested
Bebington	Mr. E. W. Cox.
Flash	Dr. Beddoe.

Flash is a village at the junction of Cheshire, Derbyshire, and Staffordshire, formerly the haunt of thieves and gipsies. 'Flash' language is said to have been coined there.

Staffordshire.

Places	By whom suggested
Biddulph Moor	Dr. J. T. Arlidge.
Goldsitch	" "

Dr. Arlidge, of Stoke-upon-Trent, remarks that the lapse of the last twenty or thirty years has obliterated almost all ethnological and ethnographical features in that part of Staffordshire by the vastly increased facilities for removal from native soil, by the extension of education,

destruction of dialects and of local superstitions, beliefs, and practices, and by the introduction of immigrants, especially attracted by the mining and manufacturing operations there pursued. Hence it is that the population is greatly mixed with Irish and Welsh; still, peculiarities of dialect prevail, resembling generally those of Yorkshire and Lancashire. North Staffordshire is by no means rich in monuments and remains of ancient culture. Until the present century it was little known. The higher regions were moorland or forest, and very thinly inhabited. A few so-called Druidical monuments remain, but tumuli are very scarce. Of Roman remains he knows none, except some roads of cross-country character. Biddulph Moor has a peculiar race of inhabitants, rapidly dying out, popularly attributed to the introduction of some individual from the East by one of the lords of Biddulph. They are peculiar in physiognomy and in language. There was also a peculiar race, well-nigh extinct, in the moorland near Leek, off the road to Buxton, in a locality known as the Goldsitch mines. There are several fine encampments of British and Saxon times.

Shropshire.

Place	By whom suggested
Clun	Mr. Geo. Luff.

This village, in the south-west corner of the county, ten miles from the Craven Arms junction of the Shrewsbury and Hereford Railway, and about eight miles from Broome, on the Central Wales line, the nearest railway station, lies sleepily in its own little hollow, encircled by hills 1,000 to 1,400 feet high, and out of the beaten track from anywhere. The result of Mr. Luff's nine years' diligent researches is to show a strong and important neolithic settlement, with its centre upon Rock Hill, communicating by a long mountain ridge with central Wales, and protected on the English side every way by a network of formidable hill fortresses. This position was continuously occupied by neolithic men, overlapping the bronze period probably down to historical times. The fusion of race with the Celts may have taken place before the final defeat of Caractacus (which Mr. Luff holds to have taken place at Shrewsbury), but then occurred a great dispersion. The large Roman camp near Craven Arms probably marks the centre of attack by Ostorius, but afterwards one small garrison planted behind Clun seems to have been sufficient to keep the remaining hill populations in order. Mr. Luff found no bronze, though outside the ring of earthworks bronze relics are common. The collection of flint and stone implements made by him is declared by Professor Boyd Dawkins to be all neolithic.

Norfolk.

Places	By whom suggested
Fishing villages along the coast	Right Hon. T. H. Huxley.
Ormesby	Dr. Beddoe.
Brandon	"
The Fen District	Rev. Augustus Jessopp, D.D.
The Wiggenhalls	" "
Dunwich	" "
Sheringham	Mr. Coutts Trotter.

Mr. Huxley states that a careful ethnographical survey of the fishing villages along the east coast of Great Britain from Pegwell Bay to Wick would be likely to yield interesting results. Many years ago, when he

was a Sea Fishery Commissioner, and later as Salmon Fishery Inspector, he was very much struck with the uniformity of type in the inhabitants of some of these villages. The fishing population often keeps itself very much to itself; and, indeed, he found on the Norfolk coast adjacent villages of fishermen distinctly hostile to one another, each being careful to accuse the others of all breaches of the fishery laws which take place. In north-east Scotland the same type is of course very strong, the names of some of the villages being pure Norse.

Brandon is the site of the flint industry.

Of the country round Ormesby Broad, north of Yarmouth, Mr. T. V. Holmes, F.G.S., remarks that, although a railway now runs through it, it must still retain much that is primitive. The Danes appear to have settled there at an early period, as the place-names Ormesby, Filby, Rollesby, &c., attest. Like Thanet, this Ormesby district was an island 1,000 years ago, although now connected with the rest of Norfolk by marshes, as Thanet is with Kent. There are probably as many place-names ending in *-by* in the Ormesby district as in all the rest of Norfolk. It would be interesting to compare this district with those of Mersea and Canvey in Essex.

Dr. Jessopp, who is rector of Scarning, East Dereham, observes that all the Norfolk peasantry are perpetually on the move, and it is now extremely hard to find a dozen men in any parish whose great grandfathers or even grandfathers were living there a century ago. Most permanence of settlement will be found in the fens, including marshland, and the coast.

At Sheringham the inhabitants are noted for their small feet, and were, till recently, almost entirely endogamous.

Northampton.

Places	By whom suggested
Thorney	Dr. Beddoe.
Croyland	„

Warwick.

Henley-in-Arden	Dr. Beddoe.

Suffolk.

Stowmarket	Miss Layard.
Bilderton	„
Branford	„

Worcester.

Teme Valley	Mr. J. W. Willis Bund, F.S.A.
Martley	„ „
Clifton-on-Teme	„ „
Bellhoughton	„ „
Cloudesley Corbett	„ „
Lenche	„ „
Inthlavan	„ „
Eldersfield	„ „

Mr. Bund remarks that this county has always seemed to him to be the meeting place of two lines of people, the Welsh up to the Severn, and a mixed race beyond to the east.

Hereford.

Places	By whom suggested
Dorstone	The Rev. J. O. Bevan.
Madley	,, ,,
Hereford City	,, ,,
Eardisland	,, ,,
Kington	,, ,,
Leominster	,, ,,
Bromyard	,, ,,
Bosbury	Dr. Beddoe.
The Golden Valley	Professor Rhys.
Longtown	Mr. J. E. Southall.
Woolthorpe	Mr. W. C. Lucy.

Dorstone is a parish near the Welsh border, where the people are said to possess blended characteristics of both races. On the peculiarities of Herefordshire dialects the late Dr. Havergal and the late Mr. Flavell Edmunds have published works.

Bosbury is a little Welsh border town, probably not much disturbed.

Professor Rhys remarks that in the Golden Valley the folklore includes a story of a vision, years ago, at one of the churches, of a ghostly congregation, to whom it was being announced who should die during the coming year. The time was Halloween, about midnight. This makes the beginning of the year among the Celts, or the calends of winter, as it is called in Welsh.

In Longtown, which is separated from Llanthony by a high mountain, Mr. Southall has seen what he considered good specimens of Silurians.

Monmouthshire.

Places	By whom suggested
Llandogo	Mr. J. E. Southall.
Llanfaches or Goldcliff	,, ,,
Llanover or Gostoe	,, ,,
The Black Mountains	,, ,,
Llanthony	,, ,,
Cwmysy	,, ,,
Cusop	,, ,,

Mr. Southall does not consider that Monmouthshire presents a good field for branches one and two of the inquiry. There are some common physical types representative of the district, but the field for the examination of villages is much narrowed by the very considerable migration of population that has taken place during this century. The agricultural population have to some extent gone to the works, and their places have been filled by English people. In Llanthony and Cwmysy the population got mixed after the establishment of the abbey in the twelfth century. The population of Cusop, near Hay, is, or was not long ago, a representative one.

Gloucester.

Places	By whom suggested
Mitcheldean	Dr Beddoe.
Stow-on-the-Wold	,,
Moreton-in-Marsh	,,
Sheepscombe	Mr. W. C. Lucy.
Avening	,,

In Moreton, which has nothing to do with marshland, but is Moreton on the boundary of three counties, the Anthropometric Committee obtained some excellent typical photographs, by the kindness of Miss Whitmore-Jones, of Chastleton. These will be available for the use of this committee. Avening is in a retired valley, through which a road was, for the first time, made about forty years ago. Until then, so closely did the inhabitants keep themselves that they allowed no one to marry out of the village; they hated strangers, and had a reputation for wildness and everything that was bad. They are more civilised now, but still very conservative.

ESSEX.

Places	By whom suggested
Mersea Island	Mr. Holmes.
Canvey Island	,,
Villages on the Roding	,,
Castle Hedingham	,,

Mr. W. Cole, Hon. Secretary of the Essex Field Club, states that East Mersea is extremely interesting from the survival there of primitive ways and modes of thought. Being away from the railways and tourist routes, and its people having little intercourse with the outside world, it is a good spot for the study of local folklore. In spots like Mersea and Canvey Islands (as in Sheppey and Thanet, south of the Thames), the Danes were wont to form more or less permanent stations, and Mersea is mentioned as a Danish station in the 'Saxon Chronicle,' A.D. 895. The villages on the upper part of the Roding probably furnish the most unmixed examples of the free Danish population, but on the other hand Mersea and Canvey are free from the later Huguenot element, so strong in Colchester, Bramtree, and other inland districts of the county.

WILTS.

Places	By whom suggested
Malmesbury	Dr. Beddoe.
Clyffe Pypard	Mr. Lewis.
Avebury	,,
Aldbourne	,,

Between Abury and Swindon there are still some poor remains of megalithic structures.

SOMERSET.

Places	By whom suggested
Cannington	Mr. F. W. Hembry, F.R.M.S.
Stowey	,,
Combwich	,,
Stogursey	,,
Charlwich	,,
Cheddar	,,
Banwell	,,
Winscombe	,,
Eaton	Mr. Elworthy.
Winsford	,,
Kingsbrompton	,,
Hawkridge	,,
South Cadbury	,,
Barton St. David's	Rev. C. W. Bennett.

The inhabitants of some of the villages named by Mr. Hembry have been of the same families for very many years, perhaps centuries. They are all agricultural villages and (except Cheddar and Winscombe) far removed from any railway.

In those named by Mr. Elworthy the people have lived for the most part, for many generations, little mixed. On the other hand, Mr. Bennett states that at Sparkford, thirty-five miles from Bath, the village of which he is rector, nearly every inhabitant has been changed within his own memory, and the dialect is rapidly disappearing.

Devon.

Places	By whom suggested
Appledore	Mr. T. Morris Jones, F.G.S.
Northam	" "
Dartmoor	Mr. A. L. Lewis.
East Budleigh	Mr. Elworthy.
Hemyock	"
Dunkerswell	"
Luppit	"
Meshaw	"
Twitching	"
East and West Anstey	"
West Down	"
Widecombe-in-the-Moor	"
Buckfastleigh	"
Beer	Dr. Beddoe.
Lydford	"

Mr. Jones remarks that, forty years ago, the people of the towns named by him retained many customs or the memory of many customs lost in larger towns. As to each of them the great majority were related, and the family feeling was remarkably strong: they sympathised in each other's joys and sorrows, and reciprocally borrowed and lent to a strange extent. Vessels from Appledore were manned by relatives almost entirely, so far as the coasting trade went, and the large brigs and barques that were in the timber trade between Bristol and Canada, or which carried emigrants, were largely commanded by Appledore captains and manned by Appledore crews, the men often objecting to the admission of a 'stranger.' These men are largely descendants of those who vexed the Spaniards and manned the Bideford whaling fleet in or about the time of Queen Elizabeth, which fleet was the next to that of Hull in importance. While Kilkhampton (in North Cornwall) was noted for its Puritan spirit, Appledore was looked upon forty years ago by the people of that neighbourhood as being a place in which no one who feared the Lord would live. There were many alive at that time who recollected the fact of being taught to pray that God would send a ship ashore before morning. The Appledore men were, however, more noted than the North Cornishmen for first saving life. Seventy to fifty years ago the men of Appledore used to fearlessly venture 'over the bar' in the worst weather in order to rescue crews. They had no lifeboats, but rowed out in long eight- to twelve-oared galleys. The Appledore people spoke a well-marked variety of the Devonshire dialect. Schools have now almost destroyed it, the result being a mongrel speech with a much more decided nasal twang than forty years ago.

Beer is a fishing and lace-making village on the borders of Dorset and Devon.

CORNWALL.

Places	By whom suggested	
Kilkhampton	Mr. T. Morris Jones.	
Stratton[1]	Mr. G. H. Fox.	
Camelford[1]	"	
St. Columb[1]	"	
Bodmin[1]	"	
Liskeard[1]	"	
Grampound[1]	"	
Gwennap[2]	"	
St. Day[2]	"	
Camborne[2]	"	
St. Just[2]	"	
Polperran[3]	"	
Portloe[3]	"	
Portscatha[3]	"	
Cadgwith[3]	"	
Porthleven[3]	"	
Mousehole[3]	"	
Porthgwara[3]	"	
Lennen[3]	"	
Wendron[4]	Mr. R. J. Connock and	Rev. Alex. R. Eagar, D.D.
Sithney[4]	"	"
Breage[4]	"	"
Germoe[4]	"	"
The Meneage		
St. Mawgan	"	"
St. Martin	"	"
Manaccan	"	"
St. Keverne	"	"
St. Anthony	"	"
St. Grade	"	"
Ruan Major	"	"
Ruan Minor	"	"
Landewednack	"	"
Mullion	"	"
Cury	"	"
Gunwalloe	"	"

Mr. Fox remarks that there is little doubt that in some Cornish villages, especially in fishing villages, the race has continued for generations without any influx of new blood. In the mining districts the men move about as mines close or open up in different places, and some go abroad to mines and return.

Mr. Connock states that previous to about the year 1840 few changes took place among the inhabitants of the whole area of which the town of Helston is the centre. The families comprising the population had been nearly all stationary for generations, and it was not difficult to meet with persons of advanced age who had never travelled beyond the nearest market town. Naturally this condition of things begot a strong love of home, and it is probable that no people, as a whole, possessed a stronger attachment to their native country than Cornishmen, who now seem called upon to be the pioneers of civilisation; and, more than the people of any other province, are scattered over the whole earth. The opening

[1] Agricultural villages. [2] Mining villages. [3] Fishing villages.
[4] Mining villages in the north and west of Helston.

up of new mining fields has, of course, had most to do with bringing about these new conditions. The ground in Cornwall had been mined for thousands of years, and the extraction of ores from deep mines had become expensive, and made it difficult to compete with new countries, where operations were carried on scarcely beyond the light of day. At first, a few tore themselves from home and gradually, as its necessity became apparent, the spirit for emigration has become almost universal, so that it is rare to meet with a young man who does not look forward to the time when he shall have to seek a wider field in which to push his fortunes than is to be found at home. The spirit of enterprise that began in the mining districts quickly extended all through, and the population within the last fifty years has in many of the parishes diminished considerably more than one-half.

In the Breage mining districts it used to be a subject of remark that 'the men were like trees,' tall and finely developed; among them the families of Gundry, Treglohans, Magors, Penhales, and others were well known, and for many years supplied the men that made the Western wrestlers the acknowledged champions of the sport. As in other places, where a number of persons having similar names existed, nicknames or cognomens were common: one of these, 'Bendigo,' from Breage, was that of the discoverer of the famous goldfields in Australia, which promptly took and retained the appellation.

Under the ancient system of mining (Mr. Connock further observes), before the introduction of the steam engine made deep mining practicable, the business of farming was generally combined with it, the late summer and autumn, when the springs became low and the work in the fields for the year nearly completed, being devoted to the mining. It is possible, he thinks, that the more recent practice of continuous employment in deep mines may have had in some cases a deteriorating effect upon the race. The small area of the enclosures in West Cornwall indicates the way in which the fields were gradually reclaimed from the waste by hand labour.

There are faint traditions of the former existence of a race of large men once living in the locality. During some repairs to the chancel of the church at Wendron about 1860 two stone coffins were discovered containing human remains of unusual size.

At Breage and Germoe were the homes of the Godolphins, the revivers of mining industry in Cornwall at the close of the fifteenth century; of William Lemon, the great miner and merchant of the early part of the eighteenth century; and of Edward Pellew, afterwards Viscount Exmouth. In these parishes the steam engine was first applied to mining on a large scale, and afterwards the labours of Arthur Woolf and Thomas Richards largely helped to bring it to its present perfection. The use of combined cylinders, which has recently effected great economy in marine navigation, was originated and put in practice in the Breage mines by them. The Cornish miners are able mechanics, wonderfully apt at expedients to meet exigencies.

The fishing village of Porthleven contains a large and increasing number of families drawing a maintenance from fisheries. They are almost wholly descended from those who have been long resident in the locality, though fishing, as a steady and continuous industry, is a calling of very recent growth. The seine fishery for capturing the shoals of pilchards periodically visiting the coast was formerly one of the great

industries of the county, but this only required the attention of those engaged during a short time of each year. This form of fishing has now almost entirely disappeared.

South of a line drawn across from the town of Helston to the mouth of Helford River, the population of the Lizard peninsula is almost entirely agricultural, and for many centuries has probably had little admixture from any outside source. The prevalence of certain names near the Lizard point has suggested a strain of Spanish extraction. As in the mining districts, emigration has of late years become general, and most of the rising youth look forward to seeking wider fields in foreign lands. During the last half-century each successive census shows a large diminution in the population. The inhabitants are generally robust and, if they escape pulmonary disease, long-lived. The proportion of tall, big men is said to be large, and it is reported that the Meneage Rifle Corps, when standing shoulder to shoulder, occupies more space than an equal number of men of any other corps in the kingdom.

About the coast, fishing is carried on to a considerable extent, but most of those engaged follow other pursuits at times when the weather or season is not suitable for that industry. Formerly, when opportunity offered, few of the people objected to a little contraband trading; and during the war it is said that this was winked at by the Government of that day, as the pursuit was thought to be a good training for seamen for the navy, to which, as well as to the army, the whole district furnished a large contingent in proportion to the population.

The extension of railways, yearly bringing an increasing number of visitors into the district, cannot fail materially to modify the character of the people. Generally they are intelligent and industrious, and have, probably, throughout the prolonged agricultural depression, maintained their ground as well as any agriculturists in the kingdom. The prevalence of Methodism has greatly modified their characteristics, a love of reading and desire for information being encouraged and looked for, in the young people especially, as they become identified with the society. Mr. Connock mentions a representative instance of this in the case of the late Mr. Samuel James, of St. Keverne.

Of original traditions and beliefs there are but the barest traces remaining, and these are vanishing. Among a few of the most ignorant a sort of covert faith in charms and witchcraft lingers, which even they are ashamed to acknowledge. Some years since a white witch and wizard contrived to exact contributions from some dupes scattered about.

Near Germoe 'Lane End' (that is, the road leading from the main road between Helston and Penzance to the church town of Germoe) once lay beside the turnpike road three boulders or stones of about 1 cwt. each. The place is locally called 'Tre-men-Keverne.' Tradition says that St. Just once paid a visit to his brother saint at St. Keverne, and was well received and entertained by him. St. Keverne, after the departure of his visitor, discovered that his silver spoons and plate were missing. Very angry at such ingratitude he started off in pursuit, picking up on his way across Crowta Downs the three stones, which he placed in his pocket to be ready for emergencies. The culprit being overtaken and the booty recovered, the stones were dropped, but the principals parted in anger. St. Just told St. Keverne that, although the people of his parish should find mineral, there should never be a regular lode within the sound of his church bells. 'As for you,' retorted St. Keverne, 'although the

people of your parish shall have plenty of fish, they shall never have a harbour to bring them into.' Both these curses are still in operation.

The Tolvan, or holed stone, near Gweek, on the borders of Wendron parish, was formerly in repute as a means of curing weak or rickety infants, who were brought, often from a distance, to be passed through the hole. The stone itself is a large granite slab, formerly lying in an inclined position in the corner of a croft. A cottage having been built on the site, a slice broken off from the stone is now made to do duty as part of the garden wall, the opening in the stone being stuffed with straw or thorns.

The Dowsing Rod still finds some who have faith in it. Of this Mr. Connoch has furnished some curious instances. Stories of its success are current, even among the most intelligent.

The vicar of Manaccan, Dr. Eagar, states that, while the majority of the inhabitants of the two villages in his parish, Manaccan church town and Helford, are strangers to the village by birth, they are all natives of the Meneage or south country. This district is in many ways so peculiar that an ethnographic survey of the kingdom should certainly contain some account of it. The 'Meneage' (*i.e.*, probably 'stony' district) consists of twelve parishes lying south of Helford River and a line passing from Gweek at the head of that river through Helston. It is thus the peninsula whose southern point is the Lizard. Dr. Eagar has noticed the existence of a very strongly marked melanochroic type among the inhabitants, and, on inquiry, has found that the persons who represent that type are of families that have belonged to the district as far back as they can trace, though not necessarily to any specified neighbourhood within the district. He has noticed the same type in county Kerry, Ireland. As seen in Cornwall, it is a very handsome type. The number of handsome *men* in his parish is very remarkable, and, for some curious reason, physical beauty seems commoner there among men than among women. The women of this type are often very handsome too—gipsy-looking, with sallow complexions and very bright eyes. Some of the men of this type look almost like Spaniards. The suggestion that this is due to an intermixture of Spanish blood from the Armada seems to Dr. Eagar to be improbable, and he thinks it due to the greater presence of a non-Aryan element in the population. The *physique* of the people is good. The men are well built, and many of the women have beautiful figures as well as faces. Phthisis is almost unknown, and death before old age is very rare. Three years ago 10 per cent. of the population of Manaccan (357 in 1881, 379 in 1891) were upwards of seventy, and not one of them was bedridden; one woman, aged eighty-eight, is so now. The dialect still exists among the old people. Plurals in *-en* are common: a boarded floor, for instance, is 'the *planchen*.' This occurs all over Cornwall. Thus, near Falmouth, the blackthorn blossoms are 'sloen-blowth.' The final verbal *-e* obtains largely, and has even a living force. 'All the people do *clarké* there,' said a parish clerk of a church where the whole congregation said the responses. So, too, they say 'to milké' and 'to clunké'—*i.e.*, to swallow. In the district round Manaccan the bluetit is called 'patenapāli'; a pullet is a 'mabyle.' Among Christian names are many 'Hannibals'; in the oldest register 'Gwalter' and 'Gwilliam' often occur; 'Loveday' is not uncommon among girls. Surnames are either place-names, mostly in 'Tre-,' or patronymics, as in Wales, such as Williams, Richards,

Thomas, Giles, Roberts, James, Rogers (the same family for at least two hundred years). The people are very warm and kindly, quick-witted, and keen. Their faults are characteristically Celtic: they are not very 'straight,' and are exceedingly suspicious; they fall out easily among themselves, but do not make up again easily; feuds go on from year to year, and last out lifetimes. They have a very curious habit of giving, by preference, any reason for their action except the one that has really determined it, and one of their own proverbs credits them with 'wearing their corns outside their boots.' The fishing villages are said to contain a distinct race, and their inhabitants differ in character from the inland folk. The non-fisherman Cornishman, even when he lives on the sea-shore, is afraid of the sea, and credits it with containing, just below low-water mark, 'villos' and sand-cliffs and other dangers. Dr. Eagar considers that the results of close intermarriage in the fishing villages are lamentable. Newlyn, near Penzance, contains two villages—Street-Nowyn (*i.e.*, 'newyn' or new) and Newlyn Town. If a Street-Nowyn woman marries a Newlyn Town man her own relatives will not visit her, and a man from one village passing through the other gets hooted in the street. The Cornish Celt is prolific and exceedingly prone to sexual irregularity.

Dorset.

Places	By whom suggested
Litton Cheney	Mr. Elworthy.
Abbotsbury	"
Askerswell	"
Puncknoll	Lieut. G. M. Mansel, R.N.
Swyre	Mr. Elworthy.

The Rev. Dr. Colby states that there are numerous prehistoric remains in the valley, which extends from Little Brady to the sea at Burton Bradstock. Till recently it was very much cut off from the rest of the world. The people have intermarried to a great extent, and many of the same names can be traced back a long way.

Mr. Mansel states that in 1891 Puncknoll had a population of 423, decreasing, as it was over 480 in 1881. The inhabitants are partly agricultural and partly fishing (seine for mackerel, herring, and sprats). The village is essentially old-fashioned, having been 'left' by the railways; and for nearly a century—viz., from 1752 to 1844—the living was held by the lords of the manor, three successive rectors, named George Frome. Old customs have been preserved, and there are many small freeholds in the parish. Physically the inhabitants are an exceptionally fine race, and very musical.

Hampshire.

Places	By whom suggested
Meon Valley	Very Rev. G. W. Kitchin, F.S.A., Dean of Winchester.
New Forest	" "
Test Valley	Rev. R. H. Clutterbuck, F.S.A.
Ringwood	Dr. Beddoe.
Fordingbridge	"

Dean Kitchin states that the whole Meon valley, the home of the Jutes (the Meonwara), is very secluded and primitive. People there say that they can distinguish the Jutish population from all others. The

valley runs from (say) Botley to Bishop's Waltham through Meonstoke, Carhampton (in the church of which parish there is an unspoilt bit of Anglo-Saxon work), Droxford, West Meon, and East Meon. The chief part of the valley is seven or eight miles from any railway. The New Forest also contains some very primitive places. The Rev. G. N. Godwin, of East Boldre, a parish seven miles from the nearest station, believes that his village, which has a distinctly Celtic name, is in the main a Celtic community almost untouched by the outside world. There are numerous barrows all around, and he believes them to be literally the graves of the leaders among his parishioners' ancestors. In no other way can many traits of character which prevail among them be understood. One of the tumuli is known as 'Colt Pixey's cave.'

Mr. Clutterbuck, who is rector of Penton Mewsey, states that the Test valley parishes, including the 'Anne' lot round Andover, have a character of their own. The valley is very clearly marked out by the high ground enclosing it; a tribal boundary runs on one side, on the opposite Wiltshire joins it; and the valley is the limit of the manor and hundred (with foreign hundred) of Andover. Of this manor the rolls exist back to an early date, and the tythingmen's returns are in many cases preserved, so that by them, as far back as the sixteenth century, and by the rolls of the gild merchant to a much earlier date, the names of pretty well all the inhabitants are known. The migration from village to village probably greatly exceeded the emigration from the valley and manor itself. The existence of the same name through a long period is very striking in the corporation records. The dialect is marked more by grammatical structure than by difference of verbal forms. There are some barrows (two in Penton Mewsey), a dyke, some camps, and two intersecting Roman ways. There is a very interesting chain of evidence of the growth of local government. Not only does historical evidence point to the commencement of the port of Andover, but the configuration of the ground upon which the town is built and that of the town itself show how the port was fenced in. The parish of Penton Mewsey, which was a separate manor, unlike the rest in the valley, has 274 inhabitants.

Sussex.

Place	By whom suggested
Rye	Dr. Beddoe.

Dr. Beddoe also suggests some village near the centre of the Weald.

SOUTH WALES.

Radnor.

Places	By whom suggested
Knighton	Dr. Beddoe.
Presteign	"
Llanigon	Mr. E. Sidney Hartland, F.S.A.
St. Harmon	Mr. Stephen W. Williams, F.S.A.
New Radnor	" "
Llanbadarn Fynnydd	" "
Glasewin	" "
Llansaintffraid Cwmdanddwr	" "
Llananno	Archdeacon Thomas.

The two small border towns named by Dr. Beddoe are probably little disturbed. Llanigon is a mountain parish. The villages named by

Mr. Williams are all more or less remote from main lines of communication, and many families must have lived in them respectively for generations.

CARDIGAN.

Places	By whom suggested
Taliesin	Mr. J. W. Willis-Bund, F.S.A.
Tregaron	" "
Llanddewibrefi	" "
Llangranog	" "
Llechryd	" "
Strata Florida	Mr. S. W. Williams.

The villages named by Mr. Bund are selected with the view of exemplifying different types of Welshmen. In some there are persons of ninety years and upwards.

PEMBROKE.

Places	By whom suggested
Freystrop	Dr. Beddoe.
Haroldston	"
Herbrandstown	"
Langum	"
Castlemartin	Rev. Iorwerth Gray Lloyd, F.S.A.
Roose	"

Mr. Lloyd, who is vicar of Bosherston, states that Langum is inhabited by fisher folk, who for ages have kept themselves apart from their neighbours as a separate community. The people in the hundreds of Castlemartin and Roose are a mongrel race.

The northern part of Pembrokeshire is particularly rich in prehistoric remains that have never been properly explored. The valleys and slopes of the Preceli mountains are extremely remote from the world. The cliff carters and other earthworks are very numerous in Pembrokeshire, also Ogam inscribed stones and other relics of early Welsh Christianity.

Mr. Lloyd furnishes a word just heard by him, in addition to the recorded dialect-vocabulary of South Pembrokeshire, viz., 'vorrier' = headland, signifying the strip by one of the hedges in a ploughed field which is often left uncultivated (see Law's 'Little England beyond Wales'; Fenton's 'Pembrokeshire'; and Owen's 'Pembrokeshire').

CARMARTHEN.

Place	By whom suggested
Cynfil Caio	Dr. Beddoe.

BRECON.

Ystradgynlais	Mr. Hartland.

GLAMORGAN.

Gower	Mr. Hartland
Ystradfellte	Mr. Arthur J. Williams, M.P.
Llangynwyd	" "
Llanport Major	" "
Cowbridge	" "
Margam	Mr. T. C. Evans.
Glyncorrwg	"

Upon the general question as regards the conditions of life in the

pastoral and agricultural districts of Wales Mr. Hartland states that the Welsh do not gather much in villages. The peasants live chiefly in homesteads, scattered over a larger or smaller area. The population of Gower is divided by a sharply defined line between the English and Welsh. This line corresponds roughly with the line dividing the coal measures from the limestone. On the latter, the southern side, are descendants of immigrant settlers from the opposite coast, or, as is sometimes thought, from Flanders, who appear to have driven out the Welsh. They speak English exclusively; they have well-recognisable characteristics; and their families have lived on the same spot, or at least in the same neighbourhood, for many generations. On the northern side, the less fertile, and formerly in every way the less desirable, the Welsh-speaking inhabitants remain, having distinct characteristics. Of late years there has been an influx of foreign population around the mines and works, but it is possible there are still spots where the old inhabitants remain almost unadulterated. Ystradfellte, a small village at the top of the valley through which the Mellte, a tributary of the Neath River, runs, is the centre of a very secluded wild and rugged district. The people are Welsh mountaineers, engaged in pastoral and agricultural work. A number of interesting traditions were collected not very far away by a lady and sent to Croker, and they appear in the third volume of his 'Fairy Legends and Traditions of the South of Ireland.' Mr. Hartland thinks it likely, from his own experience, that many still survive.

Mr. Williams says that, though the extraordinary growth of the county during the last twenty years has transformed the villages of the mining districts into towns, there are still some left in the hilly parts, and there are very old and curious villages in the Vale of Glamorgan which remain very much what they were many generations back.

For all Welsh antiquities 'Archæologia Cambrensis' should be consulted.

NORTH WALES.

Carnarvon.

Places	By whom suggested
Llanfihangel-y-Pennant	Archdeacon Thomas.
Llanengon	" "
Pwllheli	" "

Denbigh.

Llansannan	Archdeacon Thomas.
Gwytherin	" "
Cerrig-y-Druidion	" "
Yspytty	" "
Llangwm	" "
Llangernyw	" "

Merioneth.

Llanuwchllyn	Rev. Professor Ellis Edwards.
Brithdir	" "
Llanarmon Dyffryn Ceiriog	" "
Llanymowddwy	Archdeacon Thomas.

Flint.

Rhosermor	Professor Edwards.

At this village, and for some miles round it, a very marked peculiarity of intonation, believed to be unique in North Wales, is to be observed.

Montgomery.

Places	By whom suggested
Garthbeibio	Archdeacon Thomas.
Llanbrynmair	" "
Llangynog	" "
Pennant	" "

A list of twenty-six Montgomeryshire villages has also been furnished by Mr. R. Williams, of Newtown.

ISLE OF MAN.

Places	By whom suggested
Michael	Mr. A. W. Moore.
Ballaugh	" "
Maughold	" "
Cregneith	" "

Viewing the fact that since the beginning of the century the population has shifted a good deal, a small area like the Isle of Man would have to be taken as a whole. Except some very slight differences of pronunciation in Manx, and a slightly larger preponderance of the Scandinavian in the northern part, Mr. Moore is unable to trace any difference between the north and south of the isle, and the difference between the smaller districts is imperceptible. Miss Crellin remarks that the natives in many parts of the island are quite capable of cramming, and do cram, the English man of science.

SCOTLAND.

The Hebrides.

Place	By whom suggested
Ness, Butt of Lewis	Dr. Beddoe.

This is very Scandinavian.

The Highlands.

Places	By whom suggested
Moran	Dr. Beddoe.
Arisaig	"
Durness, including Melness	Rev. James Macdonald.
Assynt	" "
Durinish	" "
Kilmuir	" "
Knoidart	" "
Brae Lochaber	" "
Freswick	" "
Dunnet	" "
Camsbay	" "
Dunleath	" "
Wick	" "

As regards the Celtic area, there are no old villages of any size. Highlanders never lived in villages, but there are many traditions still floating among people who live in scattered hamlets. In each of the districts named by Mr. Macdonald the people have lived undisturbed for hundreds of years, and each is characteristic of certain phases of Celtic thought. Winter is the time to visit these districts, as it is simply

impossible to induce a Highlander to talk of his ghosts and fairies in broad daylight, and the visitor (who must of course talk Gaelic) would have to incur, besides his hotel bills, some small outlay on whisky to induce men to talk freely and throw off the ordinary restraint Highlanders have in the presence of strangers. There are colonies of gipsies near Wick who have lived in caves from time immemorial.

See also the remarks of Mr. Huxley *ante* 'Norfolk.'

FIFE.

Places	By whom suggested
Buckhaven [1]	Dr. Beddoe.
St. Monance [1]	"

THE LOWLANDS.

Lesmahagow	Dr. Beddoe.
Leadhills	"
Wenlockhead	"
Lauder	"
Hightae	Lieut.-Colonel Frederick Bailey.
Ferryden	" "
Yetholm	" "

At Hightae (Dumfriesshire) the people have been settled for upwards of 500 years. Ferryden is inhabited by people of Norse origin, and Yetholm by a gipsy race.

Mr. D. Christison remarks that in most parts of the Scottish lowlands, since the introduction of railways, there has been a great shifting of the population and an inroad of Irish, which, with the almost complete Anglicising of the upper classes in the country districts, is rapidly extinguishing the Scottish character of Scotland; but there are plenty of quiet, retired villages which still retain something of their primitive population. At Dundee intermarriage between the Irish and Scots, which at first was unusual, has now become quite common.

IRELAND.

This part of the United Kingdom will be investigated by the Sub-Committee for Ireland under the auspices of the Royal Irish Academy. Communications for the Sub-Committee should be addressed to Professor Haddon, as secretary, at the Royal College of Science, Dublin.

The preceding tables show that in the islands of Great Britain there are more than 250 places which, in the opinion of competent authorities, would be suitable for ethnographic survey. The opinions of the eminent persons who have favoured the Committee with this advice show that, notwithstanding the rapid changes which have taken place during the last fifty years in all parts of the country, much valuable material remains for the Committee to work upon. They confirm the considerations which were urged upon the Association when the appointment of this committee was asked for as to the necessity of proceeding with the work without delay if it is to be carried into effect at all.

The Committee have therefore prepared, for the use of those who have expressed their readiness to help in this matter, the following circular letter and forms of schedule:—

[1] Fishers' villages.

'DEAR SIR,—Referring to our previous circular letter, and to your obliging offer of assistance in answer to it, we have now the pleasure to enclose Forms of Schedule, which will, we trust, enable you to furnish the desired information with respect to the district mentioned by yourself.

'You will observe that a separate page or pages of foolscap has been prepared for each head of the inquiries, on which are questions and hints prepared by a member of the Committee, who has undertaken to digest the answers in respect of his particular branch, the lower portion of each page, to which should be added as many separate sheets of foolscap as may be required, being left for your answers. And that, with regard to the physical observations, a single page of foolscap has been set aside for the measurements of each individual to be observed. We shall be obliged by a note from you, stating how many individuals you think you will have the opportunity of photographing and measuring, in order that we may supply you with the requisite number of copies of the form.

'We are sure you will excuse our urging what may at first sight appear to be trivial details, but which are in reality of great practical importance to those who have to arrange and consult a large collection of communications from different persons. These are that the communications should all be written on foolscap paper, and that the writing should be on one side only of the page, and should never run so near the margin as to be an obstacle to future binding.

'The Committee are satisfied that the value of the returns will be much reduced if they do not give information under all the several heads. If it should happen, therefore, that your own pursuits or means of information do not enable you to fill up the whole of the forms desired, they would take it as a particular favour if you could induce friends to supply the missing details, and thus to render the information complete.

'The Committee, in addressing you individually, wish to disclaim any idea of interfering with the action of local Societies, from many of which, on the contrary, they have reason to expect very valuable assistance. If it should suit your convenience to present to your local Society an even fuller account of your observations than may be necessary to comply with the requirements of this Committee, such a course would be highly desirable, and it is hoped that the local Societies will, on the other hand, give to the observers in their several districts all the encouragement and moral assistance that may be found practicable.—We are, &c.'

1. *Physical Types of the Inhabitants.*

PHOTOGRAPHIC PORTRAITS.

Facial characteristics are conveniently recorded by means of photographs, taken in the three ways explained below. Amateurs in photography are now so numerous that it is hoped the desired materials may be abundantly supplied. At least twelve more or less beardless male adults and twelve female adults should be photographed. It will add much to the value of the portrait if these same persons have also been measured. The photographs should be mounted on cards, each card bearing the name of the district, and a letter or number to distinguish the individual portraits; the cards to be secured together by a thread passing

loosely through a hole in each of their upper left-hand corners. Three sorts of portrait are wanted, as follows:—

(*a*) A few portraits of such persons as may, in the opinion of the person who sends them, best convey the peculiar characteristics of the race. These may be taken in whatever aspect shall best display those characteristics, and should be accompanied by a note directing attention to them.

(*b*) At least twelve portraits of the *left* side of the face of as many different adults of the same sex. These must show in each case the *exact* profile, and the hair should be so arranged as fully to show the ear. All the persons should occupy in turn the same chair (with movable blocks on the seat, to raise the sitters' heads to a uniform height), the camera being fixed throughout in the same place. The portraits to be on such a scale that the distance between the top of the head and the bottom of the chin shall in no case be less than $1\frac{1}{4}$ inch. Smaller portraits can hardly be utilised in any way. If the incidence of the light be not the same in all cases, they cannot be used to make composite portraits. By attending to the following hints the successive sitters may be made to occupy so nearly the same position that the camera need hardly be refocussed. In regulating the height of the head it is tedious and clumsy to arrange the proper blocks on the seat by trial. The simpler plan is to make the sitter first take his place on a separate seat with its back to the wall, having previously marked on the wall, at heights corresponding to those of the various heights of head, the numbers of the blocks that should be used in each case. The appropriate number for the sitter is noted, and the proper blocks are placed on the chair, with the assurance that what was wanted has been correctly done. The distance of the sitter from the camera can be adjusted with much precision by fixing a looking-glass in the wall (say five feet from his chair), so that he can see the reflection of his face in it. The backward or forward position of the sitter is easily controlled by the operator, if he looks at the sitter's head, over the middle of the camera, against a mark on the wall beyond. It would be a considerable aid in making measurements of the features of the portrait, and preventing the possibility of mistaking the district of which the sitter is a representative, if a board be fixed above his head *in the plane of his profile*, on which a scale of inches is very legibly marked, and the name of the district written. This board should be so placed as just to fall within the photographic plate. The background should be of a medium tint (say a sheet of light brown paper pinned against the wall beyond), very dark and very light tints being both unsuitable for composite photography.

(*c*) The same persons who were taken in side face should be subsequently photographed in *strictly* full face. They should occupy a different chair, the place of camera being changed in accordance. Time will be greatly saved if all the side faces are taken first, and then all the full faces; unless, indeed, there happen to be two operators, each with his own camera, ready to take the same persons in turn. The remarks just made in respect to *b* are, in principle, more or less applicable to the present case; but the previous method of insuring a uniform distance between the sitter and the camera ceases to be appropriate.

It is proposed that composites of some of these groups shall be taken by Mr. Galton, so far as his time allows.

Physical Observations on Individuals.

Number	Date of Measurement	Surname	Christian Name	Age	Sex	Town or Village	County

SURNAMES,	SURNAME of your Father if different from your own	SURNAME of your Mother before she was married	What district do your Father's people come from?	Your Mother's?

Have your Father's people occupied that part of the country for long: if not, state what you know of their original locality.	Occupation

GENERAL CONDITION: (1) stout; (2) medium; (3) thin. | Photographed (?).

SKIN: (1) pale; (2) ruddy; (3) sallow. | Freckled (?).

HAIR: (R) red; (F) fair; (B) brown; (D) dark; (N) black.
(1) straight; (2) wavy; (3) curly.

AMOUNT OF HAIR ON FACE: (0) absent; (1) scanty; (2) medium; (3) abundant.

EYES: (1) blue; (2) grey, light or dark; (3) green; (4) hazel, light or dark.

SHAPE OF FACE: (1) long and narrow; (2) medium; (3) short and broad. (I.) Pyramidal, *i.e.*, narrowing upwards; (II.) wedge-shaped, *i.e.*, narrowing downwards; (III.) square; (IV.) round; (A) flat; (B) prominent; (*a*) cheek-bones inconspicuous; (*b*) cheek-bones prominent.

PROFILE OF NOSE: Compare with outline figures on back, and give the number with which the nose under examination most closely corresponds.

LIPS: (1) thin; (2) medium; (3) thick.

EARS: max. length; (A) flat; (B) outstanding; (*a*) coarse; (*b*) finely-moulded.

LOBES OF EARS: (1) absent; (2) present; (*a*) attached; (*b*) detached.

HEIGHT		CRANIUM			FACE			
Standing	Sitting	Length	Breadth	Height	Length	Upper Face Length	Breadth	Bigonial Breadth

NOSE		Internal Bi-ocular Breadth	AURICULAR RADII			
Length	Breadth		Cranial Height	Nasal	Alveolar	Mental

REMARKS.

Observer's Signature ____________

Directions for Measurement.

The instruments required for these measurements are—Garson's 'Traveller's anthropometer,' manufactured by Aston and Mander, 25 Old Compton Street, London, price 3*l.* 3*s.* complete; without box footpiece 2*l.* 10*s.*; a standard for measuring height, or a tape-measure fastened vertically on a wall, with the zero just level with the floor; a pair of Broca's callipers; and a Dublin boxwood craniometer for the head measurements, manufactured by Robinson and Sons, Grafton Street, Dublin, price 1*l.* 10*s.*

Height standing.—The subject should stand perfectly upright, with his back to the standard or fixed tape, and his eyes directed horizontally forwards. Care should be taken that the standard or support for the tape is vertical. The height is measured by placing a carpenter's square or a large set-square against the support in such a manner that the lower edge is at right angles to the scale; the square should be placed well above the head, and then brought down till its lower edge feels the resistance of the top of the head. The observer should be careful that the height should be taken in the middle line of the head. If the subject should object to take off his boots, measure the thickness of the boot-heel and deduct from stature indicated in boots.

Height sitting.—For this the subject should be seated on a stool or low bench, having behind it a graduated rod or tape with its zero level with the seat; he should sit perfectly erect, with his back well in against the scale. Then proceed as in measuring the height standing. The square should be employed here also if the tape against a wall is used.

Length of head.—Measured from the projection between the eye-brows (glabella) to the most distant point at the back of the head in the *middle line*. For this measurement the callipers are used, and care should be taken to keep the end on the glabella steady by holding it there with the fingers while the other extremity is searching for the maximum projection of the head behind.

Breadth of head.—The maximum breadth of head is measured at right angles to the length. Care must be taken to hold the instrument so that both its points are exactly on the same horizontal level.

Height of head.—The head should be so held that the eyes look straight forwards. The callipers of Garson's anthropometer should be held vertically in front of the face of the subject, and the upper straight arm should be extended as far as possible, and placed along the middle line of the head; the shorter lower arm should be pushed up to the lower surface of the chin.

Face length.—This is measured from the slight furrow which marks the root of the nose to the under part of the chin. Should there be two furrows, as is often the case, measure from the upper one.

Upper face length.—From root of nose to the separation between the two central front teeth at their roots.

Face breadth.—Maximum breadth of face between the bony projections in front of the ears.

Bigonial breadth.—Breadth of face at the angles of the lower jaw below the ears.

Nose length.—From the furrow at root of nose to the angle between the nose and the upper lip in the middle line.

Breadth of nose.—Measured horizontally across the nostrils at the widest part, but without compressing the nostrils.

Internal bi-ocular breadth.—Width between the internal angles of the eyes. While this is being measured the subject should shut his eyes.

Head height.—This is taken with the Dublin craniometer, the plugs of which should be well inserted into the ear-holes, so as to press against the bony wall, and the sliding indicator brought down on the top of the head, at a point vertical to the ear-hole, the head being so held that the eyes are directed to a point at the same level as themselves, *i.e.*, the plane of vision should be exactly horizontal.

Auriculo-nasal radius.—From centre of ear-hole to root of nose.

Auriculo-alveolar radius.—From centre of ear-hole to gum at root of front teeth of the upper jaw.

Auriculo-mental radius.—From centre of ear-hole to point of chin.

For these three measurements the Dublin craniometer should be used.

Cephalic index $= \frac{\text{head breadth} \times 100}{\text{head length}}$.

Height index $= \frac{\text{head height} \times 100}{\text{head length}}$.

Face index $= \frac{\text{face breadth} \times 100}{\text{face length}}$.

Nasal index $= \frac{\text{nose breadth} \times 100}{\text{nose length}}$.

Alveolar index $= \frac{\text{auriculo-alveolar } r \times 100}{\text{auriculo-nasal } r}$.

NOTE.—It is essential that these rules should be strictly followed in order to secure accuracy. If possible, the subject's weight should be obtained, and recorded in the place set apart for remarks. The observer is recommended to procure 'Notes and Queries on Anthropology,' the Anthropological Institute, 3 Hanover Square, London; net price, 3*s.* 6*d.*

The detailed measurements, for which a special schedule is provided for each person measured, form the most important part of our anthropometric investigations. In addition to this, however, we would impress upon observers the necessity for far more numerous observations than can be collected by the former method. If these are made in any part of the country whenever opportunity presents itself, we shall not only have a mass of valuable material, but we shall have suggestions as to where it might be profitable to prosecute more detailed investigation.

We would recommend observers to attend village fairs and festivals, and to provide themselves with a sufficient number of marking cards. It would be advisable for two or more observers to work independently on the same occasion; the average results of two or more observers would be of more value than the report of a single observer.

On the back of each card should be written the general impression, not only of the hair and eye colour, but also of other characteristics and peculiarities; this should be recorded immediately after the observation has been made, and not from memory after an interval.

It must be distinctly understood that this is to be regarded as supplemental to the more detailed measurements, and that the latter should receive most attention.

The anthropological data most readily obtainable are the colour of the hair and eyes. The marking cards introduced by Dr. Beddoe are in every way admirably adapted for field work, since they are small enough to fit in a waistcoat pocket. As the noting of an individual can be made by a single pencil mark, they admit of rapid and accurate use in situations where writing would be difficult. The cards are marked as in the diagram on page 647, which, also, will be found to be a convenient size.

Each card is divided vertically into three main divisions for eye colour: light, medium, and dark respectively. The three spaces thus formed are further subdivided vertically into five columns for the five hair colours: red, fair, brown, dark, and black. These are indicated by the letters R, F, B, D, and N at the heads of the columns. The card is subdivided by a horizontal line into two equal parts—the upper for males, the lower for females. It is convenient to leave a space at the end of the card for the

name of the locality and the date. The back of the card can be utilised for further particulars. The initialling of the card by the observer indicates that the record is completed for that card.

	Light eyes					Medium eyes					Dark eyes					
	R	F	B	D	N	R	F	B	D	N	R	F	B	D	N	
Males																
Females																

Care should be taken to note only such cases as can be seen clearly at close quarters, and in a good light—a precaution very necessary for the estimation of doubtful tints, especially of the eyes. Cases in which the hair has begun to turn grey should be excluded.

Adolescents who appear to be under eighteen years of age should be noted on special cards.

The eyes are classed as follows:—

Light.—All blue, bluish grey, and light grey eyes.

Medium.—Dark grey, brownish grey, very light hazel or yellow, hazel grey (formed by streaks of orange radiating into a bluish grey field), and most shades of green.

Dark.—The so-called black eyes, and those usually called brown and dark hazel.

The following are the hair colours:—

Red.—All shades which approach more nearly to red than to brown, yellow, or flaxen.

Fair.—Flaxen, yellow, golden, some of the lightest shades of brown, and some pale auburns in which the red hue is not very conspicuous.

Brown.—The lighter shades of brown.

Dark.—The darker shades of brown.

Black (*Niger*).—Which includes not only the jet black which has retained the same colour from childhood, and is generally very coarse and hard, but also that very intense brown which occurs in people who in childhood have had dark brown (or in some cases deep red) hair, but which in the adult cannot be distinguished from coal-black except in a very good light.

The foregoing scheme is taken from Dr. Beddoe's 'The Races of Britain; a Contribution to the Anthropology of Western Europe' (1885). It might be advisable to discriminate in some way (say by making a different mark in the N column) between jet black and black brown.

The collections under this head will be digested by Dr. Garson and Professor Haddon.

2. *Current Traditions and Beliefs.*

Folklore.

Every item of folklore should be collected, consisting of customs, traditions, superstitions, sayings of the people, games, and any superstitions connected with special days, marriages, births, deaths, cultivation of the land, election of local officers, or other events. Each item should be written legibly on a separate piece of paper, and the name, occupation, and age of the person from whom the information is obtained should in all cases be carefully recorded. If a custom or tradition relates to a particular place or object, especially if it relates to a curious natural feature of the district, or to an ancient monument or camp, some information should be given about such place or monument. Sometimes a custom, tradition, or superstition may relate to a particular family or group of persons, and not generally to the whole population; and in this case care should be exercised in giving necessary particulars. Any objects which are used for local ceremonies, such as masks, ribbons, coloured dresses, &c., should be described accurately, and, if possible, photographed; or might be forwarded to London, either for permanent location, or to be drawn or photographed. Any superstitions that are believed at one place and professedly disbelieved at another, or the exact opposite believed, should be most carefully noted.

The following questions are examples of the kind and direction of the inquiries to be made, and are not intended to confine the inquirer to the special subjects referred to in them, nor to limit the replies to categorical answers. The numbers within brackets refer to the corresponding articles in the 'Handbook of Folklore' (published by Nutt, 270 Strand, London).

(4) Relate any tradition as to the origin of mountains or as to giants being entombed therein.
Are there any traditions about giants or dwarfs in the district? Relate them.
Is there a story about a Blinded Giant like that of Polyphemus?

(13) Describe any ceremonies performed at certain times in connection with mountains.

(16) Relate any traditions or beliefs about caves.

(19) Are any customs performed on islands not usually inhabited? Are they used as burial places?

(25) Describe any practices of leaving small objects, articles of dress, &c., at wells.

(29) Are there spirits of rivers or streams? Give their names.

(32) Describe any practices of casting small objects, articles of dress, &c., in the rivers.

(33) Are running waters supposed not to allow criminals or evil spirits to cross them?

(39) Describe any customs at the choosing of a site for building, and relate any traditions as to the site or erection of any building.

(42) Is there a practice of sprinkling foundations with the blood of animals, a bull, or a cock?

(43) Does the building of a house cause the death of the builder?

(48, 49, 50) Relate any traditions of the sun, moon, stars.

(62) Describe the customs of fishermen at launching their boats.
(63) Give any omens believed in by fishermen.
(66) Is it unlucky to assist a drowning person?
(84) What ceremonies are performed when trees are felled?
(85) Describe any custom of placing rags and other small objects upon bushes or trees.
(86) Describe any maypole customs and dances.
(87) Describe any customs of wassailing of fruit trees.
(90) Are split trees used in divination or for the cure of disease?
(98) Describe any ceremonies used for love divination with plants or trees.
(105) Describe the garlands made and used at ceremonies.
(110) What animals are considered lucky and what unlucky to meet, come in contact with, or kill?
(132) Describe any customs in which animals are sacrificed, or driven away from house or village.
(133) Describe customs in which men dress up as animals.
(137) Give the names of the local demons, fairies, pixies, ghosts, &c. Have any of them personal proper names?
(139) Their habits, whether gregarious or solitary. Do they use special implements?
(140) Form and appearance, if beautiful or hideous, small in stature, different at different times.
(144) Character, if merry, mischievous, sulky, spiteful, industrious, stupid, easily outwitted.
(145) Occupations, music, dancing, helping mankind, carrying on mining, agricultural work.
(146) Haunts or habitations, if human dwellings, mounds, barrows, mines, forests, boggy moorlands, waters, the underworld, dolmans, stone circles.
(190) Give the details of any practices connected with the worship of the local saint.
(191) Are sacrifices or offerings made to the local saint, on what days, and when?
(192) What is the shrine of the local saint?
(210) Witchcraft. Describe minutely the ceremonies performed by the witch. What preliminary ceremony took place to protect the witch?
(294) Are charms used to find evil spirits and prevent their moving away?
(295) Are amulets, talismans, written bits of paper, gestures, &c., used to avert evil or to ensure good? If so, how, when, where?
(297) Are skulls of animals, or horses, or other objects hung up in trees to avert the evil eye and other malign influences?
(298) What methods are employed for divining future events? What omens are believed in?
(353) What superstitions are attached to women's work as such?
(356) Are women ever excluded from any occupation, ceremonies, or places?
(358) What superstitions are attached to the status of widowhood?
(366) Are particular parts of any town or village, or particular

sections of any community entirely occupied in one trade or occupation?

(368) Have they customs and superstitions peculiar to their occupation?

(369) Do they intermarry among themselves and keep aloof from other people?

(373) Have they any processions or festivals?

(422) What parts of the body are superstitiously regarded?

(432) Are bones, nails, hair, the subject of particular customs or superstitions; and is anything done with bones when accidentally discovered?

(436) Is dressing ever considered as a special ceremonial; are omens drawn from accidents in dressing?

(452) Are any parts of the house considered sacred?

(453) Is the threshold the object of any ceremony; is it adorned with garlands; is it guarded by a horseshoe or other object?

(454) Are any ceremonies performed at the hearth; are the ashes used for divination; is the fire ever kept burning for any continuous period?

(456) Is it unlucky to give fire from the hearth to strangers always, or when?

(467) Is there any ceremony on leaving a house, or on first occupying a house?

(509) What are the chief festivals, and what the lesser festivals observed?

(515) Explain the popular belief in the object of each festival.

(516) Describe the customs and observances appertaining to each festival.

(540) When does the new year popularly begin?

State the superstitions or legends known to attach to—

(*a*) Halloween (both old and new styles).
(*b*) May Eve.
(*c*) Midsummer day, and St. John's Eve.
(*d*) Lammas, or August 1.
(*e*) New Year's Day.
(*f*) Christmas.

Is there any superstition as to the first person who enters a house in the New Year? Is stress laid upon the colour of complexion and hair?

(567) What are the customs observed at the birth of children?

(588) Describe the ceremonies practised at courtship and marriage.

(623) Describe the ceremonies at death and burial.

(669) Describe any games of ball or any games with string, or other games.

(674) Describe all nursery games of children.

(686) Is there any special rule of succession to property?

(703) Is any stone or group of stones, or any ancient monument or ancient tree connected with local customs?

(706) Are any special parts of the village or town the subject of particular rights, privileges, or disabilities; do these parts bear any particular names?

(711) Describe special local modes of punishment or of lynch law.

(719) Describe special customs observed at ploughing, harrowing, sowing, manuring, haymaking, apple gathering, corn harvest, hemp harvest, flax harvest, potato gathering, threshing, flax picking, and hemp picking.

The collections under this head will be digested by Professor Rhys and the representatives of the Folklore Society.

3. *Peculiarities of Dialect.*

Directions to Colllectors of Dialect Tests.

1. Do not, if it can be helped, let your informant know the nature of your observations. The true dialect speaker will not speak his dialect freely or truly unless he is unaware that his utterance is watched. In some cases persons of the middle class can afford correct information, and there is less risk in allowing them to know your purpose.

2. Observe the use of consonants. Note, for example, if *v* and *z* are used where the standard pronunciation has *f* and *s*. This is common in the south.

3. Observe very carefully the nature of the vowels. This requires practice in uttering and appreciating vowel sounds, some knowledge of phonetics, and a good ear.

4. Record all observations in *the same* standard phonetic alphabet, viz., that given in Sweet's 'Primer of Phonetics.' A few modifications in this may be made, viz., *ng* for Sweet's symbol for the sound of *ng* in *thing*; *sh* for his symbol for the *sh* in *she*; *ch* for his symbol for the *ch* in *choose*; *th* for the *th* in *thin*; *dh* for the *th* in *then*. If these modifications are used say so. But the symbol *j* must only be used for the *y* in *you*, viz., as in German. If the sound of *j* in *just* is meant Sweet's symbol should be used. On the whole it is far better to use no modifications at all. Sweet's symbols are no more difficult to use than any others after a very brief practice, such as every observer of phonetics must necessarily go through.

5. If you find that you are unable to record sounds according to the above scheme it is better to make *no return at all*. Incorrect returns are misleading in the highest degree, most of all such as are recorded in the ordinary spelling of literary English.

6. The chief vowel-sounds to be tested are those which occur in the following words of English origin, viz., *man, hard, name, help, meat* (spelt with *ea*), *green* (spelt with *ee*), *hill, wine, fire, soft, hole, oak* (spelt with *oa*), *cool, sun, house, day, law,* or words involving similar sounds. Also words of French origin, such as *just, master* (*a* before *s*), *grant,* (*a* before *n*), *try, value, measure, bacon, pay, chair, journey, pity, beef, clear, profit, boil, roast, pork, false, butcher, fruit, blue, pure, poor,* or words involving similar sounds.

The best account of these sounds, as tested for a Yorkshire dialect, is to be found in Wright's 'Dialect of Windhill' (English Dialect Society, 1892), published by Kegan Paul at 12*s.* 6*d.* Sweet's symbols are here employed throughout.

Sweet's 'Primer of Phonetics' is published by the Oxford Press at 3*s.* 6*d.*

A list of text-words (of English origin) is given at p. 42 of Skeat's 'Primer of English Etymology,' published by the Oxford Press at 1*s.* 6*d.*

7. The task of collecting words which seem to be peculiarly dialectal (a to form or meaning, or both) has been performed so thoroughly that it is useless to record what has been often already recorded. See, for example, Halliwell's (or Wright's) 'Provincial Glossary' and the publications of the English Dialect Society. In many cases, however, the *pronunciation* of such words has not been noted, and may be carefully set down with great advantage.

The Rev. Professor Skeat has been kind enough to draw up the foregoing directions, and the collections under this head will be submitted to him.

4. *Monuments and other Remains of Ancient Culture.*

Plot on a map, describe, furnish photographs on sketches, and state the measurements and names (if any) of these, according to the following classification:—

Drift implements. Caves and their contents.
Stone circles. Monoliths. Lake dwellings.
Camps. Enclosures. Collections of hut circles.
Cromlechs. Cairns. Sepulchral chambers.
Barrows, describing the form, and distinguishing those which have not been opened.
Inscribed stones.
Figured stones. Stone crosses.
Castra (walled). Earthen camps.
Foundations of Roman buildings.
Cemeteries (what modes of sepulture).
Burials, inhumation or cremation.
Detailed contents of graves.
Types of fibulæ and other ornaments.
Coins. Implements and weapons, stone, bronze, or iron.
Other antiquities.
A list of place-names within the area. No modern names required.

Special note should be made of British, Roman, and Saxon interments occurring in the same field, and other signs of successive occupation.

Reference should be made to the article 'Archæology' in 'Notes and Queries on Anthropology,' p. 176.

These relate to England only. The sub-committees for other parts of the United Kingdom will prepare modified lists.

The collections under this head will be digested by Mr. Milman and Mr. Payne.

5. *Historical Evidence as to Continuity of Race.*

Mention any historical events connected with the place, especially such as relate to early settlements in it or more recent incursions of alien immigrants.

State the nature of the pursuits and occupations of the inhabitants.

State if any precautions have been taken by the people to keep themselves to themselves; if the old village tenures of land have been preserved.

Has any particular form of religious belief been maintained?

Are the people constitutionally averse to change?

What are the dates of the churches and monastic or other ancient buildings or existing remains of former buildings?

Do existing buildings stand on the sites of older ones?

How far back can particular families or family names be traced?

Can any evidence of this be obtained from the manor rolls; from the parish registers; from the tythingmen's returns; from guild or corporation records?

Are particular family names common?

In what county or local history is the best description of the place to be found?

Evidences of historical continuity of customs, dress, dwellings, implements, &c., should be noted.

The collections under this head will be digested by Mr. Brabrook.

The Committee recommend that they be reappointed, and that a grant be made to defray the expenses already incurred and to carry on their work.

The North-Western Tribes of Canada.—Report of the Committee, consisting of Dr. E. B. Tylor (*Chairman*), Mr. G. W. Bloxam (*Secretary*), Dr. G. M. Dawson, Mr. R. G. Haliburton, *and* Mr. H. Hale, *appointed to investigate the physical characters, languages, and industrial and social condition of the North-Western Tribes of the Dominion of Canada.*

Since the death of Sir Daniel Wilson the work of the Committee in America has been directed by Mr. Horatio Hale and Dr. G. M. Dawson; during the past year, however, the state of Mr. Hale's health has rendered it imperative for him to give up the active part which he has heretofore taken in the work of the Committee, and for which they feel that they are deeply indebted to him.

The absence of Dr. Dawson from America on business connected with the Behring Sea Arbitration and the fact that the whole of Dr. Boas's time has been occupied at the World's Columbian Exhibition at Chicago have rendered it impossible for the Committee to carry out their original intention of terminating their work with this year's report.

A considerable amount of material has already been collected by Dr. Boas and Dr. Chamberlain on behalf of the Committee, and this they hope to be able to publish next year.

The Committee ask for reappointment, and, in order that they may be enabled to draw up a final report and bring their work to a close in a satisfactory manner, they ask that they may be permitted to retain and utilise any portion of last year's grant that may remain in their hands after the payment of expenses for which they have already made themselves liable.

Anthropometric Laboratory.—Report of the Committee, consisting of Sir W. H. FLOWER (*Chairman*), Dr. J. G. GARSON (*Secretary*), Mr. G. W. BLOXAM, Professor A. C. HADDON, *and* Dr. WILBERFORCE SMITH. (*Drawn up by* Dr. J. G. GARSON, *Secretary.*)

THE Committee have to report that at the Edinburgh meeting of the Association last year excellent accommodation was provided for the Anthropometric Laboratory near to the meeting-room of the Anthropological Section. The services of a clerk were, as usual, placed at the disposal of the Committee, and by the kind permission of Mr. Francis Galton those of the official measurer at his laboratory in South Kensington Museum were again available for measuring the members of the Association who visited the laboratory.

The schedule of observations and measurements made on each person examined was the same as has been used for several years past by the Committee, and includes the sex, age, birthplace, colour of eyes and hair, profile of nose, height when standing, sitting, and kneeling, vertical projection from the vertex of the head to the tragus, mouth, and chin, length and breadth of the head, length and breadth of nose, length of cubit and hand, span of arms, weight in ordinary clothing, strength of pull with each hand, vital capacity of lungs, strength of vision, sense of colour, and in males the circumference of the chest during forced inspiration and expiration respectively.

Since the close of the meeting the observations recorded during it have been carefully worked up, under the direction of the Secretary, after the plan which has been adopted in previous years.

The Committee ask to be reappointed and to have a sum of 5*l.* again placed at their disposal.

The following are the results of the observations made on the 55 males and 49 females who presented themselves for measurement at the Laboratory during the course of the meeting.

Age.—The males varied in age from 17 to 72 years. Of these 4 were under 20 years, 19 were 20 and under 30 years, 16 were 30 and under 40 years, 4 were 40 and under 50 years, 6 were 50 and under 60 years, 4 were 60 and under 70, and 2 were 70 and 72 years.

The ages of the females varied from 16 to 59 years. Four were under 20 years, 16 were 20 and under 30 years, 15 were 30 and under 40 years, 7 were 40 and under 50 years, and 7 were 50 and under 60 years.

Between the ages of 24 and 56 there were 38 males and 40 females. Ten of the males and 8 of the females were below 24 years of age, and 7 of the males and one female were over 56 years of age; 70 per cent. of the males and 82 per cent. of the females were fully developed and in the prime of life.

Birthplace and Residence.—Thirty-eight per cent. of the males were Scotch by birth, and 44 were English. The remainder were Irish and persons born in British dependencies, or foreigners from various parts of Europe.

Of the females 27 per cent. were Scotch by birth, 56 per cent. English, 8 per cent. Irish, principally from Belfast, and therefore

probably of the same racial stock as the Scotch; 8 were born in British dependencies.

The majority of both sexes measured were town dwellers, 69 per cent. of the males and 77 per cent. of the females being townspeople; while 31 per cent. of the former and 27 per cent. of the latter had lived their lives in the country.

It may be stated that residents of smaller towns were classed as country dwellers; only those who had lived the greater part of their lives in large towns or cities were included as town dwellers.

Occupation.—The larger proportion of the males were engaged in professional pursuits.

Colour of Eyes.—The colour of the iris has been classified under the three categories, light, medium, dark.

In the males 58 per cent. had light eyes, 16 per cent. medium, and 26 per cent. dark.

In the females 57 per cent. had light eyes, 27 per cent. medium, and 16 per cent. dark.

Colour of Hair.—Dividing the colour of the hair into the divisions light, medium, and dark—including red in the light group, dark brown and black in the dark group, and omitting all cases of grey hair due to senile or other changes—31 per cent. of the males had light hair, 47 per cent. medium, and 22 per cent. dark; while in the females the percentages were 22 light, 37 medium, and 41 dark.

—	Light			Medium			Dark		
	L.	M.	D.	L.	M.	D.	L.	M.	D.
Males . . .	14	15	3	1	7	1	2	4	8
Females . .	11	10	7	0	6	7	0	2	6

The above table gives the various combinations of colour of eyes and hair met with. The top headings (light, medium, and dark) refer to the colour of the eyes, while the letter headings (L., M., D.) refer to the colour of the hair. The numbers in the table show the frequency in which the several combinations occurred.

Profile Curve of Nose.—The outline of the nose as seen in profile was straight in 76 per cent. of the males and in 73 per cent. of the females; it was of the concave variety in 5 per cent. of the males and in 10 per cent. of the females; in 18 per cent. of the males and in 16 per cent. of the females one or other of the three forms of convex variety occurred. Of these the sinuous form occurred in 11 per cent. of the males and in 8 per cent. of the females, the aquiline in 3·6 per cent. of the males and in 2 per cent. of the females, and the high-bridged in 3·6 per cent. of the males and in 6·1 per cent. of the females. Illustrations of these varieties of form of the nasal profile are to be found in 'Notes and Queries on Anthropology,' Plate IV. (2nd edition), which was used in recording the observations.

Measurements.

1. *Height when Standing.*—For the sake of convenience persons were measured with their boots or shoes on their feet, but to ascertain their actual height the thickness of the heel was also measured and deducted

from the total indicated height. The stature thus obtained, as has been proved from many observations, does not err in being more than it really is, but, if anything, rather less, because usually the place where the heel of the foot rests is more or less hollowed out in the boot below the external heel level.

The stature of the males and females at the 25th, 50th, and 75th grades, according to Mr. Francis Galton's method of working out these statistics, also the probable deviation (indicated by the letter Q) which when added to the figures of the 25th grade gives the corrected mean, are as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mid-Stature
Males . .	1,692 mm.	1,738 mm.	1,773 mm.	41	1,733 mm.
Females . .	1,565 „	1,602 „	1,638 „	36	1,601 „

2. *Height when Sitting.*—This gives the length of the trunk of the body, neck, and head, which is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	888	914	939	25	913
Females . .	838	857	879	20	858

3. *Height when Kneeling.*—This measurement is of itself unimportant, but in relation to the previous measurements is very important, as it enables us to calculate the length of each of the two segments included in the length of the lower extremities, namely, the thigh and leg with the foot. It is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	1,272	1,300	1,331	29	1,301
Females . .	1,189	1,215	1,242	26	1,215

4. *Length of Lower Limbs.*—If the height when sitting be subtracted from the height when standing, the difference between these measurements will indicate the amount contributed to the stature by the lower limbs. It is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	804	824	834	15	819
Females . .	727	745	759	16	743

5. *Length of Leg and Height of Foot.*—This has been obtained by subtracting the height when kneeling from the height when standing. It is as follows :—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	420	438	442	11	431
Females . .	376	387	396	10	386

6. *Length of the Thigh Portion of the Lower Limb.*—This measurement has been obtained by subtracting the length of the leg and foot portion from the total length of the lower limbs, and is as follows:—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	384	388	392	4	388
Females . .	351	358	363	6	357

The proportions contributed by the different parts which go to make up the corrected mean stature of the males from the previous figures are as follows: head, neck, and trunk, 52·7 per cent.; the lower limbs from the level of the tuber ischia downwards, 47·3 per cent. Of the latter the thigh portion contributes 22·4 per cent. of the stature, and the leg and height of the foot 24·9 per cent.

In the females the head, neck, and trunk contribute 53·6 per cent., and the lower limbs 46·4 per cent. Of the latter the thigh portion forms 22·3 per cent., and the leg and height of the foot 24·1 per cent. of the stature.

7. *Vertical Projection of Head.*—This is the vertical length of the head from its vertex to the under-surface of the chin, and is as follows:—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean Length
Males . .	208·0	219·5	229·8	10·9	218·9
Females . .	206·4	214·0	223·4	8·5	214·9

The small difference between the vertical length of the head in the males and females is doubtless due to the fashion in which the latter dress the hair, elevating it on the top of the head, which renders it difficult to obtain this measurement with accuracy. This remark is applicable also to all measurements made from the vertex. In such measurements as the stature, where the figures are much greater than those of the head, the error is proportionately less, and consequently less observable.

8. *Vertical Length from Vertex to Mouth.*—This is measured to the line of junction of the upper and lower lips in the mesial line of the head.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean Length
Males . .	164·7	174·7	185·8	10·5	175·2
Females . .	165·9	176·3	184·3	9·2	175·1

In this measurement the remarks regarding the error in measurements from the vertex of the head in the females is still more obvious.

9. *Vertical Length from Vertex to Tragus.*—The lower point of measurement is at the pit at the upper edge of the root of the zygomatic arch, and corresponds to the middle of the tragus; it is strictly analogous to the upper edge or border of the meatus auditorius, and represents the height of the cranium from this point.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	129·8	132·7	140·6	5·4	135·2
Females . .	125·1	130·1	133·4	4·2	129·3

10. *Maximum Antero-posterior Length of Cranium.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean Length
Males . .	194·2	198·2	202·8	4·3	198·5
Females . .	182·7	186·6	190	4·3	187

11. *Maximum Transverse Breadth of Cranium.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean Breadth
Males . .	151	154·4	158·3	3·6	154·6
Females . .	143·8	148·3	150·7	3·4	147·2

12. *Proportions of the Head.*—(*a*) *The Cephalic Index*, calculated from the length and breadth of each head measured, varies from 71·6 to 83 in the males, and from 74·9 to 88·6 in the females.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean Index
Males . .	76·1	77·7	79·2	1·5	77·6
Females . .	76·5	77·6	80·2	1·8	78·3

According to the *International Divisions of the Cephalic Index*, the classification is as follows:—

—	Dolichocephalic (70–74·9)	Mesaticephalic (75–79·9)	Brachycephalic (80–84·9)
Males . . .	5	40	10
Females . . .	1	31	17
	Or in percentages		
Males . . .	9·1	72·7	18·2
Females . . .	2	63·3	34·7

(*b*) *The Module of the Cranium*, which is obtained by adding its length, breadth, and height together, adding to the product 15 mm. to represent the projection from the auditory meatus to the bases in the case of males and 13 mm. for females, and dividing the total sum thus obtained by 3. It is as follows:—

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	163·2	167	172·2	4·5	167·7
Females . .	156·7	159·3	163	3·1	159·8

(*c*) *The Total Head Breadth-length Index*, or the relation which the maximum breadth of the cranium bears to the vertical length of the head (vertex to chin), the latter being taken as 100, is 70·6 in the males and 68·5 in the females, estimated from the corrected mean lengths of the respective measurements.

(*d*) *The Maximum Granial Length to total vertical head-length* (=100)

is 90·7 in the males and 87 in the females. If the index is reversed—that is to say, the maximum length of the cranium is taken as 100—it is 110·3 in the males and 101·4 in the females.

(*e*) *The Canon of Proportion* of the vertical length of head (vertex to chin) to the stature (=100) is in the males 12·63 per cent., and in the females 13·42 per cent.

13. *Nasal Index.*—The variations of this index are very similar in both sexes, ranging from 45·6 to 75 in the males, and from 47·1 to 76·7 in the females.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	51·3	57·3	62·1	5·4	56·7
Females . .	49·6	54·8	62·3	6·3	55·9

14. *Face Index.*—The index of the face which the Committee have for some years past adopted is obtained from the length of the face, measured directly with callipers from the root of the nose to the under-surface of the chin (=100), and the maximum bizygomatic breadth of the face. This index in the living may be made to correspond with that of Kollmann on the skull by taking the zygomatic breadth as 100.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	105·9	110·4	115	4·5	110·4
Females . .	107·4	113·2	119·6	6·1	113·5

15. *Length of Cubit.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	451·5	466·5	479·3	13·9	465·4
Females . .	406·7	417·2	431	12·8	419·5

The corrected mean length of cubit in the males and females is 26·8 and 26·2 per cent. of their respective corrected mean stature.

16. *Length of Hand.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . .	189·1	193·8	200·5	5·7	194·8
Females . .	167·6	173·8	181·7	7·5	175·1

The canon of proportion of the length of the hand to the stature is in the males 11·24 per cent., and in the females 10·94 per cent.

By subtracting the corrected mean length of hand from the corrected mean length of the cubit, the mean length of the *forearm* is obtained. In the males it is 270·6 mm., and in the females 244·4 mm.; the length of the hand to the forearm in the former is 72, and in the latter 71·2. The canon of proportion of the forearm to the stature is 15·6 per cent. in the males, and in the females 15·3 per cent.

17. *Span of Arms.*

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	1,721 mm.	1,765 mm.	1,817 mm.	48	1,769 mm.
Females . .	1,535 „	1,538 „	1,638 „	52	1,587 „

As compared with the corrected mean height when standing, the corrected mean length of span is 36 millimetres greater than that of the stature in the males, while in the females the span is shorter than the mean stature by 14 millimetres. Taking the stature as 100, the proportion which the span of arms bears to it in the males is 100·2, and in the females 99. In 9 males the span of arms was shorter than the stature, but in all the others it was greater. In the females, on the other hand, in 27 cases the span of arms was less than the stature, in 18 it was greater, and in one case the two measurements were equal.

18. *Weight.*—Owing to the weighing machine and weights having to be got on the spot English pounds and ounces had to be used. The figures of weight below are consequently pounds and decimals of pounds.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	137·7	150·4	161·9	12·1	149·8
Females . .	110·7	121·5	131·0	10·8	121·5

19. *Pull.*—When the strength of pull of one arm and hand differs from that of the other, a mean of the two arms has been taken as the strength of pull of the person.

The dynamometer being graduated to English weight the following figures represent pounds and decimals of pounds.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	51·5	60·6	71·1	9·3	60·8
Females . .	27·5	31·8	37·3	4·9	32·4

In the males the right arm is the stronger in 28 out of 55 cases, or in 50·9 per cent.; the two arms are equal in 16·4 per cent. (9 cases), and the left arm is the stronger in 32·7 per cent. (18 cases). In the females the right arm is the stronger in 23 cases out of 49 cases, or in 46·9 per cent.; both arms are equal in 28·6 per cent. (14 cases), and in 24·5 per cent. the left arm is the stronger (12 cases).

20. *Vital Capacity of the Lungs.*—This was ascertained by means of Stanley's spirometer, graduated in *cubic inches,* so that the following figures represent cubic inches and decimals of cubic inches.

—	25th Grade	50th Grade	75th Grade	Q	Corrected Mean
Males . . .	188·5	222	249·3	30·4	218·9
Females . .	121·2	133·5	147·9	13·3	134·5

21. *Circumference of the Chest.*—This measurement was only ascertained on males. During forced inspiration the circumference of the chest was as follows:—

25th Grade	50th Grade	75th Grade	Q	Corrected Mean
930 mm.	967 mm.	1,008 mm.	39	969 mm.

During forced inspiration the circumference of the chest measured the following number of millimetres less than during forced expiration :—

25th Grade	50th Grade	75th Grade	Q	Corrected Mean
37	57	64	13	50

If half the difference between forced inspiration and forced expiration be subtracted from the circumference of the chest during forced inspira-

Table of Measurements of Males.

—	1892. Edinburgh. Number, 55	1891. Cardiff. Number, 73	1890. Leeds. Number, 95
Height when Standing . . .	1,733 mm.	1,731 mm.	1,720 mm.
Height when Sitting . . .	913 „	910 „	911 „
Length of Thigh	388 „	384 „	377 „
Length of Leg	431 „	436 „	431 „
Vertical Length of Head (vertex to chin)	218·9 „	214 „	213 „
Antero-posterior length of Head	198·5 „	199 „	198 „
Breadth (maximum) of Head .	154·6 „	156 „	155 „
Height of Cranium (vertex to tragus)	135·2 „	128 „	—
Cephalic Index	*77·6*	*78·3*	*78*
Module of Head	167·7 „	166 „	160 „
Nasal Index	*56·7*	*60·6*	*65*
Face Index	*110·4*	*112*	*112* „
Length of Cubit	465·4 „	465 „	464 „
Length of Hand	194·8 „	193 „	—
Span of Arms	1,769 „	1,776 „	1,769 „
Weight *in lbs.*	149·8	156	155·5
Pull *in lbs.*	60·8	67·8	65
Vital Capacity of Lungs *in cubic inches*	218·9	221	217
Maximum Circumference of Chest	969 „	976 „	—
Canon of Proportion of the Body in Males (Height =100).			
Head, Neck, and Trunk to level of *Tuber ischia*	52·7	52·6	53
Lower Limbs from level of *Tuber ischia*	47·3	47·4	47
Head	12·6	12·4	12·4
Rest of Trunk	40·1	40·2	40·6
Thigh	22·4	22·2	21·9
Leg and Height of Foot .	24·9	25·2	25·1
Cubit	26·8	25·9	26·4
Forearm	15·6	14·8	16·0
Hand	11·2	11·1	10·4

tion, the mean circumference of the chest will be obtained, which at the corrected mid-grade would be 944 millimetres.

Vision.—The power of vision was tested with Snellen's test-types placed at a distance of 6 metres from the eye. Each eye was tested separately; while one eye was being tested the other was kept open, and a black card was held over it to prevent the type being seen by it.

The number of males who could read No. 6 type with both eyes at 6 metres, and whose sight was therefore normal, was 27 out of 55, or 49·1 per cent. Of these 17, or 30·9 per cent., were able to read No. 5 type at 6 metres.

The females who were able to read No. 6 type with both eyes at 6 metres numbered 22 out of 49, or 44·9 per cent., and of these 13, or 26·5 per cent., were able to read No. 5 type at 6 metres.

In a large number of cases in both sexes the vision in the two eyes differed, that of one eye being more defective than that of the other.

The time which could be devoted to each candidate was too short to permit of any investigation as to the cause of the deficiencies in vision being undertaken.

Colour Sense.—The test-colours recommended in the Report of the Committee of the Royal Society on Colour Blindness have been adopted in testing the appreciation of colour. For this purpose a number of skeins of coloured wools were added to wools of the colour given in the plate of the just mentioned report, so as to increase the number of confusion colours. Each candidate was given the three standard skeins and told to pick out from the heap of coloured wools those that were like them in colour. No case of colour blindness was found amongst either the males or females.

The table will give some idea of the variations of the different measurements which have been obtained during the last three meetings of the Association, and of the canon of proportion of the several parts of the body.

It will also enable anyone who has been measured in the laboratory to find what his place is with respect to the corrected mean of each measurement. If he is above or below the mean in any measurement, by referring to that measurement in the report he will be able to ascertain further particulars with respect to his position. The 25th, 50th, and 75th grades are the positions which would be held by the 25th, 50th, and 75th man if a hundred men were marshalled in a row, beginning from the smallest up to the greatest, with respect to the particular measurement.

Uniformity in the Spelling of Barbaric and Savage Languages and Race Names.—Report of the Committee, consisting of Mr. FRANCIS GALTON (*Chairman*), Dr. E. B. TYLOR, Professor A. C. HADDON, Mr. G. W. BLOXAM, Mr. LING ROTH, *and* Mr. C. E. PEEK (*Secretary*).

THE Committee recommend that the system of orthography already adopted by the Royal Geographical Society, the Admiralty, the Foreign Office, the Colonial Office, the War Office, and the Government of the

United States of America be adopted by the British Association in the titles of the papers submitted to Sections E and H.

As regards barbaric languages, the Committee are not prepared to offer other suggestions than that—

1. The above-named system should be adopted so far as it is applicable.

2. That in selecting symbols to express additional sounds endeavour should be made to conform to the usage of previous authors.

3. That explanatory examples of the signification of those symbols be given by the writer.

4. That the Secretary of the British Association shall direct the attention of those travellers who may hereafter receive money grants from the Association to the above resolutions.

The system of orthography referred to above is subjoined.

The Committee request to be reappointed.

SYSTEM OF ORTHOGRAPHY FOR NATIVE NAMES OF PLACES.

Taking into consideration the present want of a system of geographical orthography, and the consequent confusion and variety that exist in the mode of spelling in English maps, the Council of the Royal Geographical Society have adopted the following rules for such geographical names as are not, in the countries to which they belong, written in the Roman character. These rules are identical with those adopted for the Admiralty charts, and will henceforth be used in all publications of the Society.[1]

1. No change will be made in the orthography of foreign names in countries which use Roman letters: thus Spanish, Portuguese, Dutch, &c., names will be spelt as by the respective nations.

2. Neither will any change be made in the spelling of such names in languages which are not written in Roman character as have become by long usage familiar to English readers; thus Calcutta, Cutch, Celebes, Mecca, &c., will be retained in their present form.

3. The true sound of the word as locally pronounced will be taken as the basis of the spelling.

4. An approximation, however, to the sound is alone aimed at. A system which would attempt to represent the more delicate inflections of sound and accent would be so complicated as only to defeat itself. Those who desire a more accurate pronunciation of the written name must learn it on the spot by a study of local accent and peculiarities.

5. The broad features of the system are that vowels are pronounced as in Italian and consonants as in English.

6. One accent only is used—the *acute*—to denote the syllable on which stress is laid. This is very important, as the sounds of many names are entirely altered by the misplacement of this 'stress.'

7. Every letter is pronounced. When two vowels come together each

[1] Since this was published in the *Proceedings* the system has been adopted by the Intelligence Division, War Office, on all précis and maps, by the Foreign and Colonial Offices, in all reports, and in the Queen's Regulations and Orders for the Army. [January 1889.]

one is sounded, though the result, when spoken quickly, is sometimes scarcely to be distinguished from a single sound, as in *ai*, *au*, *ei*.

8. Indian names are accepted as spelt in Hunter's 'Gazetteer.'

The amplification of the rules is given below:—

Letters	Pronunciation and Remarks	Examples
a	*ah*, *a* as in *father*	Java, Banána, Somáli, Bari.
e	*eh*, *e* as in *benefit*	Tel-el-Kebír, Oléleh, Yezo, Medina, Levúka, Peru.
i	English *e*; *i* as in *ravine*; the sound of *ee* in *beet* . . Thus, not *Feejee*, but	Fiji, Hindi.
o	*o* as in *mote*	Tokio.
u	long *u* as in *flute*; the sound of *oo* in *boot*. Thus, not *Zooloo*, but	Zulu, Sumatra.
	All vowels are shortened in sound by doubling the following consonant.	Yarra, Tanna, Mecca, Jidda, Bonny.
	Doubling of a vowel is only necessary where there is a distinct repetition of the single sound.	Nuulúa, Oosima.
ai	English *i* as in *ice*	Shanghai.
au	*ow* as in *how* . Thus, not *Foochow*, but	Fuchau.
ao	is slightly different from above . . .	Macao.
ei	is the sound of the two Italian vowels, but is frequently slurred over, when it is scarcely to be distinguished from *ey* in the English *they*	Beirút, Beilúl.
b	English *b*.	
c	is always soft, but is so nearly the sound of *s* that it should be seldom used. If *Celebes* were not already recognised it would be written *Selebes*.	Celebes.
ch	is always soft as in *church*	Chingchin.
d	English *d*.	
f	English *f*. *ph* should not be used for the sound of *f*. . Thus, not *Haiphong*, but	Haifong, Nafa.
g	is always hard. (Soft *g* is given by *j*) . .	Galápagos.
h	is always pronounced when inserted.	
j	English *j*. *Dj* should never be put for this sound.	Japan, Jinchuen.
k	English *k*. It should always be put for the hard *c* . . Thus, not *Corea*, but	Korea.
kh	The Oriental guttural	Khan.
gh	is another guttural, as in the Turkish . .	Dagh, Ghazi.
l, m, n	As in English.	
ng	has two separate sounds, the one hard as in the English word *finger*, the other as in *singer*. As these two sounds are rarely employed in the same locality, no attempt is made to distinguish between them.	
p	As in English.	
q	should never be employed; *qu* is given as *kw*.	Kwangtung.
r, s, t, v, w, x	As in English.	Sawákin.

Letters	Pronunciation and Remarks	Examples
y	is always a consonant, as in *yard*, and therefore should never be used as a terminal, *i* or *e* being substituted.	Kikúyu.
	Thus, not *Mikindány*, but	Mikindáni.
	not *Kwaly*, but	Kwale.
z	English *z*	Zulu.
	Accents should not generally be used, but where there is a very decided emphatic syllable or stress, which affects the sound of the word, it should be marked by an *acute* accent.	Tongatábu, Galápagos, Paláwan, Saráwak.

The Automatic Balance of Reciprocating Mechanism. *By* W. Worby Beaumont, *M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso* among the Reports.]

Vibration is often an annoying mechanical by-product representing more or less waste. In connection with some questions of vibrations of buildings and structures resulting from the working of machinery, the author was led to consider the possibility of the utilisation of the disturbing force productive of the harmful vibration, and thereby to prevent the vibration. It is generally known that to mechanical engineers the complete balance of rotary and reciprocating parts of machine, more especially those of the latter kind, offer very great difficulties, and that where these are not overcome vibration of the structures or framing carrying these parts is set up, and is of a more or less destructive character. The balance of rotating mechanism is usually only a question of care and cost, but the balance of reciprocating or combined reciprocating mechanism is not so easy. In steam engines, for instance, a good deal is done in the endeavour to balance reciprocating parts by rotating balancing weight. This, however, usually only reduces but does not remove vibration, for if a balance is effected in the direction of reciprocation some disturbance is set up in a direction generally normal thereto. Mr. Yarrow has, however, succeeded in reducing to a minimum the vibration due to the working of marine engines by opposing the motion that would otherwise occur by the inertia of bob weights. The force which would be used in vibrating the steamship is thus dissipated in a vertical direction, but vibratory effort in a horizontal direction is still experienced. Generally, objectionable vibrations in buildings, due to the working of machinery, is overcome by opposing the movement which the disturbing force tends to set up by the inertia of very heavy foundations. This method is often the only one that can be adopted; but there is the objection that the wear of the bearings of the machinery is greater in this case than it would be if it were possible to obtain perfect balance of the moving parts. In some cases the absence of this balance may be rendered harmless by the permission of controlled motion through small range of that, whatever it may be, to which such machinery is attached.

By way of illustration the simpler cases of vibration in the framing of

machinery having reciprocating parts may be referred to; such, for instance, as some classes of mining machinery, sorting and grading machinery as used in flour mills, some textile machinery, paper-making machinery, coal screens, and the like. In all the machines of this class the push and pull of the reciprocated part is attended by a corresponding pull and push against that part of the machine framing to which the bearings of the crank or other reciprocating medium are fixed. As far as possible, this is compensated by the use of balance weights on the crank shaft, but in many cases the motion which would otherwise be set up has to be opposed by the costly method of constructing very strong framing, or the often inconvenient one of employing guy ropes or stays; a method which often gives rise to vibration in the building to which these stays are attached. After attempting to prevent vibrations thus set up and to conquer this *bête noire* of mechanical engineering, the author has found that the best way to conquer it is to make use of it—to convert this mechanical by-product into a mechanical servant. This can be done in a large number of cases. Where, for instance, a part of a machine is reciprocated by means of a crank and connecting rod, the weight of which is balanced by rotating weights on the crank shaft, the whole of the vibration in the framing of the machine may be avoided by dispensing entirely with the crank and connecting rod, and using only the rotating balance weights on a shaft running in bearings which are attached, not to the framing, but to the thing which has to be reciprocated or gyrated. The crank and connecting rod being absent, the balance weights are now unbalanced except dynamically, and the want of balance is kinetically equivalent to the required motion in the thing to be gyrated. This was shown by the models placed upon the table, and by reference to a simple case as shown by the diagram exhibited.

The relation between the range of reciprocation or gyration of the part to be operated and of the rotating unbalanced weight, as well as of their respective weights, may be represented by the following expressions:—

If R=radius of gyration of part moved,
r=radius of unbalanced rotating weight,
W=weight of part to be moved,
w=weight of rotating part (W in the figures),

then

$$\frac{r}{R}=\frac{W}{w}; \qquad r=R\times\frac{W}{w};$$

$$R=\frac{r}{\left(\frac{W}{w}\right)};$$

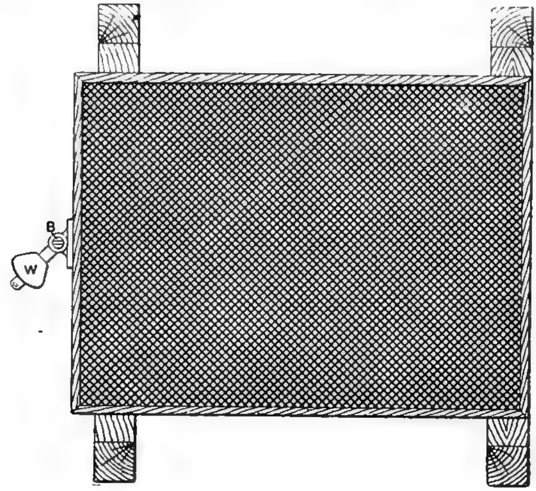
and

$$W=\frac{r}{R}\times w; \quad w=\frac{W}{\left(\frac{r}{R}\right)}.$$

In the diagram is shown a suspended screen operated in the manner described by a perfectly free rotating weight. Fig. 1 is a plan of such a screen; fig. 2, an elevation of the same with the frame partly in section; fig. 3, an end elevation of the same; fig. 4, an elevation to a larger scale of the bearing carrying the rotating weight; and fig. 5, the short spindle bracket and pulley by means of which, through the medium of a

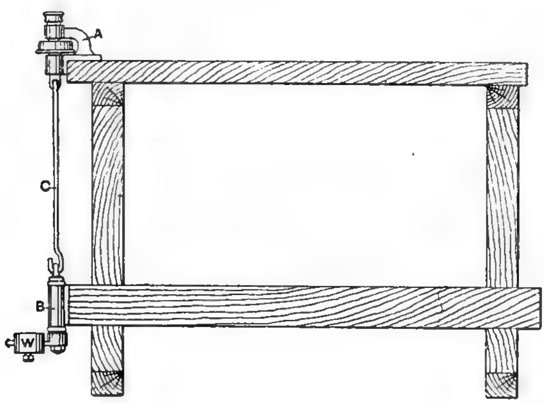
flexible or articulated connection or hooked rod, motion is communicated to the rotating weight. In figs. 2 and 3 a simple mode of connection is

FIG. 1.



shown. When the pulley in the bracket, A, is driven from some source of power, rotation at the same speed is given to the weight, W. Being

FIG. 2.



an unbalanced weight it sets up vibration in the thing to which it is attached, namely, in this case the screen, and the whole of the work done is absorbed in vibrating or gyrating the screen through a range which is proportional to the relations as to dimensions and weights already referred to. In fig. 6 is shown in plan an alternative method on the same principle, by means of which a rotating eccentric weight, W, running in bearings in a bracket, B, and driven by a flexible connection, C, imparts to the screen a reciprocating motion. In this case the range of reciprocation is limited by the mode of suspension of the screen weight, of the screen and its load when it is undesirable that the screen should be lifted by the inertia of motion of the weight, W, in the downward part of its rotating path. The movements described with reference to these diagrams are illustrated by three of the models exhibited.

Another model is exhibited with a view to illustration of the usual method of imparting reciprocating movement by means of a crank

FIG. 3.

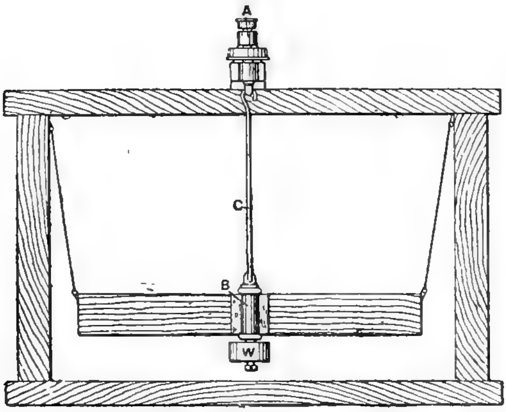
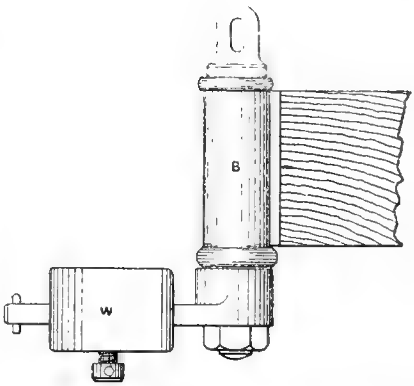


FIG. 4.



and connecting rod, and of the attainment of similar and greater movements by the simple rotating weight. This model is also illustrative

FIG. 5.

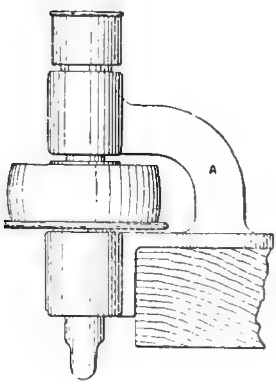
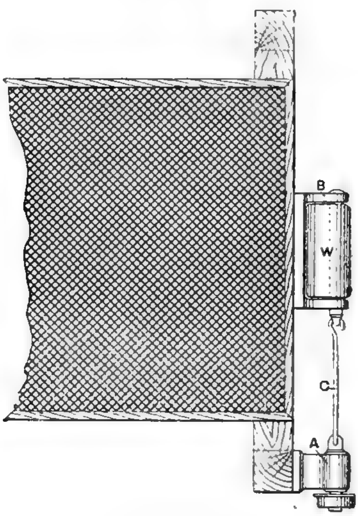


FIG. 6.



of several interesting questions bearing upon vibration due to rotating weights in machinery as set up in frames, floors, and buildings, and upon elastic vibration.

The equations on page 666 give the range of gyration when the rotating weight is in the centre of the sieve. When at the end of the screen, as shown, the gyratory path at that end is elliptical, with the major axis transverse to the sieve. At the other end the movement is of less range, the major axis of the ellipse being longitudinal.

TRANSACTIONS OF THE SECTIONS.

TRANSACTIONS OF THE SECTIONS.

Section A.—MATHEMATICAL AND PHYSICAL SCIENCE.

President of the Section—R. T. Glazebrook, M.A., F.R.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following address:—

Before dealing with the subject which I hope to bring to your notice this morning, I wish to express my deep regret for the circumstances which have prevented Professor Clifton, who had accepted the nomination of the Council, from being your President this year.

It was specially fitting that he who has done so much for this college, and particularly for this laboratory in which we meet, should take the chair at Nottingham. The occasions on which we see him are all too seldom; and we who come frequently to these meetings were looking forward to help and encouragement in our work, derived from his wide experience. You would desire, I feel sure, that I should convey to him the expressions of your sympathy. For myself I must ask that you will pass a lenient judgment on my efforts to fill his place.

Let me commence, then, with a brief retrospect of the past year and the events which concern our Section.

From the days of Galileo the four satellites of Jupiter have been objects of interest to the astronomer. Their existence was one of the earliest of the discoveries of the telescope; they proved conclusively that all the bodies of the solar system did not move round the earth. The year which has passed since our last meeting is memorable for the discovery of a fifth satellite. It is a year to-day (Sept. 13-14, 1892) since Professor Barnard convinced himself that he had seen with the great telescope of the Lick Observatory this new member of our system as a star of the thirteenth magnitude, revolving round the planet in 11 hours 57 minutes 23 seconds.[1]

The conference on electrical standards held at our meeting last year has had important results. The resolutions adopted at Edinburgh were communicated to the Standards Committee of the Board of Trade. A supplementary report accepting these resolutions was agreed to by that Committee (Nov. 29, 1892), and presented to the President of the Board of Trade. The definitions contained in this report will be made the basis of legislation throughout the world. They have been accepted by France, Germany, Austria, and Italy. The congress at Chicago which has just been held has ratified them, and thus we may claim that

[1] 'In general,' he says, 'the satellite has been faint. . . . On the 13th, however, when the air was very clear, it was quite easy.'—*Nature*, Oct. 20, 1892.

your Committee, co-operating with the leaders of physical science in other lands, have secured international agreement on these fundamental points.

Among the physical papers of the year I would mention a few as specially calling for notice. Mr. E. H. Griffiths's re-determination of the value of the mechanical equivalent of heat has just been published,[1] and is a monumental work. With untiring energy and great ability he struggled for five years against the difficulties of his task, and has produced results which, with the exception of one group of experiments, do not differ by more than 1 part in 10,000; while the results of that one excepted group differ from the mean only by 1 part in 4,000.

The number of ergs of work required to raise 1 gramme of water 1° C. at 15° C. is $4{\cdot}198 \times 10^7$. Expressed in foot-pounds and Fahrenheit degrees, the value of J is 779·77. The value obtained by Joule from his experiments on the friction of water, when corrected in 1880 by Rowland so as to reduce his readings to the air thermometer, is 778·5 at 12°·7 C. The result at this temperature of Rowland's own valuable research is 780·1. Another satisfactory outcome of Mr. Griffiths's work is the very exact accordance between the scale of temperature as determined by the comparison of his platinum thermometer with the air thermometer, which was made by Callendar and himself in 1890, and that of the nitrogen thermometer of the Bureau International at Sèvres.

Another great work now happily complete is Rowland's 'Table of Standard Wave-lengths.'[2] Nearly a thousand lines have been measured with the skill and accuracy for which Rowland has made himself famous; and in this table we see the results achieved by the genius which designed the concave grating and the mechanical ingenuity which contrived the almost perfect screw.

Those of us who have seen Mr. Higgs's wonderful photographs of the solar spectrum taken with a Rowland grating will rejoice to know that his map also is now finished.

Lord Rayleigh's paper on 'The Intensity of Light reflected from Water and Mercury at nearly perpendicular incidence,'[3] combined with the experiments on reflexion from liquid surfaces in the neighbourhood of the polarising angle,[4] establishes results of the utmost importance to optical theory. 'There is thus,' Lord Rayleigh concludes, 'no experimental evidence against the rigorous application of Fresnel's formulæ'—for the reflexion of polarised light—'to the ideal case of an abrupt transition between two uniform transparent media.'

Professor Dewar has, during the year, continued his experiments on the liquefaction of oxygen and nitrogen on a large scale. To a physicist perhaps the most important results of the research are the discovery of the magnetic properties of liquid oxygen, and the proof of the fact that the resistance of certain pure metals vanishes at absolute zero.[5] The last discovery is borne out by Griffiths and Callendar's experiments with their platinum thermometers.[6]

Mr. Williams's article on 'The Relation of the Dimensions of Physical Quantities to Directions in Space'[7] has led to an interesting discussion. Some of his deductions will be noticed later.

The title-page of the first edition of Maxwell's 'Electricity and Magnetism' bears the date 1873. This year, 1893, we welcome a third edition, edited by Maxwell's distinguished successor, and enriched by a supplementary volume, in which Professor J. J. Thomson describes some of the advances made by electrical science in the last twenty years. The subject matter of this volume might well serve as a text for a Presidential Address.

The choice of a subject on which to speak to-day has been no easy task. The field of physics and mathematics is a wide one. There is one matter, however, to which for a few minutes I should like to call your attention, inadequately though it be. Optical theories have, since the year 1876, when I first read Sir George Stokes's 'Report on Double Refraction,'[8] had a special interest for me, and I think

[1] *Phil. Trans.*, vol. clxxxiv.
[2] *Phil. Mag.*, July 1893.
[3] *Ibid.*, October 1892.
[4] *Ibid.*, January 1892.
[5] *Phil. Mag.*, October 1892.
[6] *Ibid.*, December 1892.
[7] *Ibid.*, September 1892.
[8] *British Association Report*, 1862.

the time has come when we may with advantage review our position with regard to them, and sum up our knowledge.[1]

That light is propagated by an undulatory motion through a medium which we call the ether is now an established fact, although we know but little of the nature or constitution of the ether. The history of this undulatory theory is full of interest, and has, it appears to me, in its earlier stages been not quite clearly apprehended. Two theories have been proposed to account for optical phenomena. Descartes was the author of the one, the emission theory. Hooke, though his work was very incomplete, was the founder of the undulatory theory. In his 'Micrographia,' 1664, page 56, he asserts that light is a quick and short vibratory motion, 'propagated every way through an homogeneous medium by direct or straight lines extended every way like rays from the centre of a sphere. . . . Every pulse or vibration of the luminous body will generate a sphere which will continually increase and grow bigger, just after the same manner, though indefinitely swifter, as the waves or rings on the surface do swell into bigger and bigger circles about a point on it;' and he gives on this hypothesis an account of reflexion, refraction, dispersion, and the colours of thin plates. In the same work, page 58, he describes an experiment practically identical with Newton's famous prism experiment, published in 1672. Hooke used for a prism a glass vessel about two feet long, filled with water, and inclined so that the sun's rays might enter obliquely at the upper surface and traverse the water. 'The top surface is covered by an opacous body, all but a hole through which the sun's beams are suffered to pass into the water, and are thereby refracted' to the bottom of the glass, 'against which part if a paper be expanded on the outside there will appear all the colours of the rainbow—that is, there will be generated the two principal colours, scarlet and blue, with all the intermediate ones which arise from the composition and diluting of these two.' But Hooke could make no use of his own observation; he attempted to substantiate from it his own theory of colours, and wrote pure nonsense in the attempt; and though his writings contain the germ of the theory, and in the light of our present knowledge it seems possible that he understood it more thoroughly than his contemporaries believed, yet his reasoning is so utterly vague and unsatisfactory that there is little ground for surprise that he convinced but few of its truth.

And then came Newton. It is claimed for him, and that with justice, that he was the true founder of the emission theory. In Descartes' hands it was a vague hypothesis. Newton deduced from it by rigid reasoning the laws of reflexion and refraction; he applied it with wondrous ingenuity to explain the colours of thin and of thick plates and the phenomena of diffraction, though in doing this he had to suppose a mechanism which he must have felt to be almost impossible; a mechanism which in time, as it was applied to explain other and more complex phenomena, became so elaborate that, in the words of Verdet, referring to a period one hundred years later, 'all that is necessary to overturn this laborious scaffolding is to look at it and try to understand it.'

But though Newton may with justice be called the founder of the emission theory, it is unjust to his memory to state that he accepted it as giving a full and satisfactory account of optics as they were known to him. When he first began his optical work he realised that facts and measurements were needed, and his object was to furnish the facts. He may have known of Hooke's theories. The copy of the 'Micrographia' now at Trinity College was in the Library while Newton was working with his prism in rooms in college, and may have been consulted by him. An early note-book of his contains quotations from it. Still there was nothing in the theories but hypotheses unsupported by facts, and these would have no charm for Newton. The hypotheses in the main are right. Light is due to wave motion in an all-pervading ether; the principle of interference, vaguely foreshadowed by Hooke ('Micrographia,' p. 66), was one which a

[1] This address was in the printer's hands when I saw Sir G. Stokes's paper on 'The Luminiferous Ether,' *Nature*, July 27: Had I known that so great a master of my subject had dealt with it so lately, my choice might have been different; under the circumstances it was too late to change.

century later was to remove the one difficulty which Newton felt. For there was one fact which Hooke's theory could not then explain, and till that explanation was given the theory must be rejected; the test was crucial, the answer was decisive.

Newton tells us repeatedly what the difficulty was. In reply to a criticism of Hooke's in 1672 he writes:—'For to me the fundamental supposition itself seems impossible, namely, that the waves or vibrations of any fluid can, like the rays of light, be propagated in straight lines without continual and very extravagant spreading and bending into the quiescent medium where they are terminated by it. I mistake if there be not both experiment and demonstration to the contrary. . . . For it seems impossible that any of those motions or pressions can be propagated in straight lines without the like spreading every way into the shadowed medium.'

Nor was there anything in the controversy with Hooke, which took place about 1675, to shake this belief. Hooke had read his paper describing his discovery of diffraction. He had announced it two years earlier, and there is no doubt in my mind that this was an original discovery, and not, as Newton seemed to imply soon after, taken from Grimaldi; but his paper does not remove the difficulty. Accordingly we find in the 'Principia' Newton's attempted proof (lib. ii. prop. 42) that 'motus omnis per fluidum propagatus divergit a recto tramite in spatia immota'—a demonstration which has convinced but few and leaves the question unsolved as before.

Again, in 1690 Huygens published his great 'Traité de la Lumière,' written in 1678. Huygens had clearer views than Hooke on all he wrote; many of his demonstrations may be given now as completely satisfactory, but on the one crucial matter he was fatally weak. He, rather than Hooke, is the true founder of the undulatory theory, for he showed what it would do if it could but explain the rectilinear propagation. The reasoning of the latter part of Huygens' first chapter becomes forcible enough when viewed in the light of the principle of interference enunciated by Young, November 12, 1801, and developed, independently of Young, by Fresnel in his great memoir on 'Diffraction' in 1815; but without this aid it was not possible for Huygens's arguments to convince Newton, and hence in the 'Opticks' (2nd edit., 1717) he wrote the celebrated Query 28:—'Are not all hypotheses erroneous in which light is supposed to consist in pressure or motion propagated through a fluid medium? If it consisted in motion propagated either in an instant or in time it would bend into the shadow. For pressure or motion cannot be propagated in a fluid in right lines beyond an obstacle which stops part of the motion, but will bend and spread every way into the quiescent medium which lies outside the shadow.' These were his last words on the subject. They prove that he could not accept the undulatory theory; they do not prove that he believed the emission theory to give the true explanation. Yet, in spite of this, I think that Newton had a clearer view of the undulatory theory than his contemporaries, and saw more fully than they did what that theory could achieve if but the one difficulty were removed.

This was Young's belief, who writes:[1]—'A more extensive examination of Newton's various writings has shown me that he was in reality the first who suggested such a theory as I shall endeavour to maintain; that his own opinions varied less from this theory than is now almost universally believed; and that a variety of arguments have been advanced as if to meet him which may be found in a nearly similar form in his own works.' I wish to call attention to this statement, and to bring into more prominent view the grounds on which it rests, to place Newton in his true position as one of the founders of the undulatory theory.

The emission theory in Newton's hands was a dynamical theory; he traced the motion of material particles under certain forces, and found their path to coincide with that of a ray of light; and in the 'Principia,' prop. 96, Scholium, he calls attention to the similarity between these particles and light. The particles obey the laws of reflexion and refraction; but to explain why some of the incident light was reflected and some refracted Newton had to invent his hypothesis of fits

[1] *Phil. Trans.*, November 12, 1801.

of easy reflexion and transmission. These are explained in the 'Opticks,' book iii., props. 11, 12, and 13 (1704), thus:—

'Light is propagated from luminous bodies in time, and spends about seven or eight minutes of an hour in passing from the sun to the earth.

'Every ray of light in its passage through any refracting surface is put into a certain transient constitution or state, which in the progress of the ray returns at equal intervals, and disposes the ray at each return to be easily transmitted through the next refracting surface, and between the returns to be easily reflected by it.

'*Definition.*—The return of the disposition of any ray to be reflected I will call its fit of easy reflexion, and those of the disposition to be transmitted its fits of easy transmission, and the space it passes between every return and the next return the interval of its fits.

'The reason why the surfaces of all thick transparent bodies reflect part of the light incident on them and refract the rest is that some rays at their incidence are in their fits of easy reflexion, some in their fits of easy transmission.'

Such was Newton's theory. It accounts for some or all of the observed facts; but what causes the fits? Newton, in the 'Opticks,' states that he does not inquire; he suggests, for those who wish to deal in hypotheses, that the rays of light striking the bodies set up waves in the reflecting or refracting substance which move faster than the rays and overtake them. When a ray is in that part of a vibration which conspires with its motion it easily breaks through the refracting surface—it is in a fit of easy transmission; and, conversely, when the motion of the ray and the wave are opposed, it is in a fit of easy reflexion.

But he was not always so cautious. At an earlier date (1675) he sent to Oldenburg, for the Royal Society, an 'Hypothesis explaining the Properties of Light'; and we find from the journal book that 'these observations so well pleased the society that they ordered Mr. Oldenburg to desire Mr. Newton to permit them to be published.' Newton agreed, but asked that publication should be deferred till he had completed the account of some other experiments which ought to precede those he had described. This he never did, and the hypothesis was first printed in Birch's 'History of the Royal Society,' vol. iii., pp. 247, 262, 272, &c.; it is also given in Brewster's 'Life of Newton,' vol. i., App. II., and in the 'Phil. Mag.,' September 1846, pp. 187–213.

'Were I,' he writes in this paper, 'to assume an hypothesis, it should be this, if propounded more generally, so as not to assume what light is further than that it is something or other capable of exciting vibrations of the ether. First, it is to be assumed that there is an ethereal medium, much of the same constitution with air, but far rarer, subtiller, and more strongly elastic. . . . In the second place, it is to be supposed that the ether is a vibrating medium, like air, only the vibrations far more swift and minute; those of air made by a man's ordinary voice succeeding at more than half a foot or a foot distance, but those of ether at a less distance than the hundred-thousandth part of an inch. And as in air the vibrations are some larger than others but yet all equally swift, . . . so I suppose the ethereal vibrations differ in bigness but not in swiftness. . . . In the fourth place, therefore, I suppose that light is neither ether nor its vibrating motion, but something of a different kind propagated from lucid bodies. They that will may suppose it an aggregate of various peripatetic qualities. Others may suppose it multitudes of unimaginable small and swift corpuscles of various sizes springing from shining bodies at great distances one after the other, but yet without any sensible interval of time. . . . To avoid dispute and make this hypothesis general, let every man here take his fancy; only, whatever light be, I would suppose it consists of successive rays differing from one another in contingent circumstances, as bigness, force, or vigour, like as the sands on the shore; . . . and, further, I would suppose it diverse from the vibrations of the ether. . . . Fifthly, it is to be supposed that light and ether mutually act upon one another.' It is from this action that reflexion and refraction come about; 'æthereal vibrations are therefore,' he continues, 'the best means by which such a subtile agent as light can shake the gross particles of solid bodies to heat them. And so, supposing that light impinging on a refracting or

reflecting æthereal superficies puts it into a vibrating motion, that physical superficies being by the perpetual appulse of rays always kept in a vibrating motion, and the ether therein continually expanded and compressed by turns, if a ray of light impinge on it when it is much compressed, I suppose it is then too dense and stiff to let the ray through, and so reflects it; but the rays that impinge on it at other times, when it is either expanded by the interval between two vibrations or not too much compressed and condensed, go through and are refracted. . . . And now to explain colours. I suppose that as bodies excite sounds of various tones, and consequently vibrations in the air of various bignesses, so when the rays of light by impinging on the stiff refracting superficies excite vibrations in the ether, these rays excite vibrations of various bignesses; . . . therefore, the ends of the capillamenta of the optic nerve which front or face the retina being such refracting superficies, when the rays impinge on them they must there excite these vibrations, which vibrations (like those of sound in a trumpet) will run along the aqueous pores or crystalline pith of the capillamenta through the optic nerves into the sensorium (which light itself cannot do), and there, I suppose, affect the sense with various colours, according to their bigness and mixture—the biggest with the strongest colours, reds and yellows; the least with the weakest, blues and violets; the middle with green; and a confusion of all with white.'

The last idea, the relation of colour to the bigness of wave-length, is put even more plainly in the 'Opticks,' Query 13 (ed. 1704):—'Do not several sorts of rays make vibrations of various bignesses, which according to their bignesses excite sensations of various colours; . . . and, particularly, do not the most refrangible rays excite the shortest vibrations for making a sensation of deep violet; the least refrangible the largest for making a sensation of deep red?'

The whole is but a development of a reply, written in 1672, to a criticism of Hooke's on his first optical paper, in which Newton says: 'It is true that from my theory I argue the corporeity of light, but I do it without any absolute positiveness, as the word perhaps intimates, and make it at most a very plausible consequence of the doctrine and not a fundamental supposition.' 'Certainly,' he continues, 'my hypothesis has a much greater affinity with his own [Hooke's] than he seems to be aware of, the vibrations of the ether being as useful and necessary in this as in his.'

Thus Newton, while in the 'Opticks' he avoided declaring himself as to the mechanism by which the fits of easy reflexion and transmission were produced, has in his earlier writings developed a theory practically identical in many respects with modern views, though without saying that he accepted it. It was an hypothesis; one difficulty remained, it would not account for the rectilinear propagation, and it must be rejected till it did.

Light is neither ether nor its vibrating motion; it is energy which, emitted from luminous bodies, is carried by wave motion in rays, and falling on a reflecting surface sets up fresh waves by which it is in part transmitted and in part reflected. Light is not material, but Newton nowhere definitely asserts that it is. He 'argues the corporeity of light, but without any absolute positiveness.' In the 'Principia,' writing of his particles, his words are: 'Harum attractionum haud multum dissimiles sunt Lucis reflexiones et refractiones;' and the Scholium concludes with: 'Igitur ob analogiam quæ est inter propagationem radiorum lucis et progressum corporum, visum est propositiones sequentes in usus opticos subjungere; interea de natura radiorum (utrum sint corpora necne) nihil omnino disputans, sed trajectorias corporum trajectoriis radiorum persimiles solummodo determinans.'[1]

No doubt Newton's immediate successors interpreted his words as meaning that he believed in the corpuscular theory, conceived, as Herschel says, by Newton, and

[1] The reflexions and refractions of light are not very unlike these attractions. Therefore, because of the analogy which exists between the propagation of rays of light and the motion of bodies, it seemed right to add the following propositions for optical purposes, not at all with any view of discussing the nature of rays (whether they are corporeal or not), but only to determine paths of particles which closely resemble the paths of rays.—*Principia*, lib. i., sect. xiv., prop. 96, Scholium.

called by his illustrious name. Men learnt from the 'Principia' how to deal with the motion of small particles under definite forces. The laws of wave motion were obscure, and till the days of Young and Fresnel there was no second Newton to explain them. There is truth in Whewell's words ('Inductive Sciences,' ii., chap. x.): 'That propositions existed in the "Principia" which proceeded on this hypothesis was with many ground enough for adopting the doctrine.' Young's view, already quoted, appears to me more just; and I see in Newton's hypothesis the first clear indication of the undulatory theory of light, the first statement of its fundamental laws.

Three years later (1678) Huygens wrote his 'Traité de la Lumière,' published in 1690. He failed to meet the main difficulty of the theory, but in other respects he developed its consequences to a most remarkable degree. For more than a century after this there was no progress, until in 1801 the principle of interference was discovered by Young, and again independently a few years later by Fresnel, whose genius triumphed over the difficulties to which his predecessors had succumbed, and, by combining the principles of interference and transverse vibrations, established an undulatory theory as a fact, thus making Newton's theory a *vera causa*.

There is, however, a great distinction between the emission theory as Newton left it and Fresnel's undulatory theory. The former was dynamical, though it could explain but little: the particles of light obeyed the laws of motion, like particles of matter. The undulatory theory of Huygens and Fresnel was geometrical or kinematical: the structure of the ether was and is unknown; all that was needed was that light should be due to the rapid periodic changes of some vector property of a medium capable of transmitting transverse waves. Fresnel, it is true, attempted to give a dynamical account of double refraction, and of the reflexion and refraction of polarised light, but the attempt was a failure; and not the least interesting part of Mr. L. Fletcher's recent book on double refraction ('The Optical Indicatrix') is that in which he shows that Fresnel himself in the first instance arrived at his theory by purely geometrical reasoning, and only attempted at a later date to give it its dynamical form. 'If we reflect,' says Stokes,[1] 'on the state of the subject as Fresnel found it and as he left it, the wonder is, not that he failed to give a rigorous dynamical theory, but that a single mind was capable of effecting so much.' Every student of optics should read Fresnel's great memoirs.

But the time was coming when the attempt to construct a dynamical theory of light could be made. Navier, in 1821, gave the first mathematical theory of elasticity. He limited himself to isotropic bodies, and worked on Boscovitch's hypothesis as to the constitution of matter. Poisson followed on the same lines, and the next year (1822) Cauchy wrote his first memoir on elasticity. The phenomena of light afforded a means of testing this theory of elasticity, and accordingly the first mechanical conception of the ether was that of Cauchy and Neumann, who conceived it to consist of distinct hard particles acting upon one another with forces in the line joining them, which vary as some function of the distances between the particles. It was now possible to work out a mechanical theory of light which should be a necessary consequence of these hypotheses. Cauchy's and the earlier theories do not represent the facts either in an elastic solid or in the ether. At present we are not concerned with the cause of this; we must recognise them as the first attempts to explain on a mechanical basis the phenomena observed. According to this theory in its final form, there are, in an isotropic medium, two waves which travel with velocities $\sqrt{A/\rho}$ and $\sqrt{B/\rho}$, A and B being constants and ρ the density. Adopting Cauchy's molecular hypothesis, there must be a definite relation between A and B.

A truer view of the theory of elasticity is given by Green in his paper read before the Cambridge Philosophical Society in 1837. This theory involves the two constants, but they are independent, and to account for certain optical effects A must either vanish or be infinite. The first supposition was, until a few years since, thought to be inconsistent with stability; the second leads to consequences which in part agree with the results of optical experiment, but which differ fatally from those

[1] 'Report on Double Refraction,' *Brit. Assoc. Report*, 1862, p. 254.

results on other points. And so the first attempt to construct a mechanical theory of light failed. We have learnt much from it. At the death of Green the subject had advanced far beyond the point at which Fresnel left it. The causes of the failure are known, and the directions in which to look for modifications have been pointed out.

Now I believe that the effort to throw any theory into mechanical form, to conceive a model which is a concrete representation of the truth, to arrive at that which underlies our mathematical equations wherever possible, is of immense value to every student. Such a course, I am well aware, has its dangers. It may be thought that we ascribe to the reality all the properties of the model, that, in the case of the ether, we look upon it as a collection of gyrostatic molecules and springs, or of pulleys and indiarubber bands, instead of viewing it from the standpoint of Maxwell, who hoped, writing of his own model, 'that by such mechanical fictions, anyone who understands the provisional and temporary character of his hypothesis will find himself helped rather than hindered in his search after the true interpretation of the phenomena.' Professor Boltzmann, in his most interesting paper on 'The Methods of Theoretical Physics,'[1] has quoted these words, and has expressed far more ably than I can hope to do the idea I wish to convey.

The elastic solid theory, then, has failed; but are we therefore without any mechanical theory of light? Are we again reduced to merely writing down our equations, and calling some quantity which appears in them the amplitude of the light vibration, and the square of that quantity the intensity of the light? Or can we take a further step? Let us inquire what the properties of the ether must be which will lead us by strict reasoning to those equations which we know represent the laws of the propagation of light.

These equations resemble in many respects those of an elastic solid; let us, then, for a moment identify the displacement in a light-wave with an actual displacement of a molecule of some medium having properties resembling that of a solid. Then this medium must have rigidity or quasi-rigidity in order that it may transmit transverse waves; at the same time it must be incapable of transmitting normal waves, and this involves the supposition that the quantity A which appears in Green's equations must vanish or be infinite. To suppose it infinite is to recur to the incompressible solid theory; we will assume, therefore, that it is zero. Reflexion and refraction show us that the ether in a transparent medium such as glass differs in properties from that in air. It may differ either (1) in density or effective density,[2] or (2) in rigidity or effective rigidity. The laws of double refraction and the phenomena of the scattering of light by small particles show us that the difference is, in the main, in density or effective density; the rigidity of the ether does not greatly vary in different media. Dispersion, absorption, and anomalous dispersion all tell us that in some cases energy is absorbed from the light-vibrations by the matter through which they pass, or, to be more general, by something very intimately connected with the matter.

We do not know sufficient to say what that action must be; we can, however, try the consequences of various hypotheses. Guided by the analogy of the motion of a solid in a fluid, let us assume that the action is proportional to the acceleration of the ether particles relative to the matter, and, further, that under certain circumstances some of the energy of the ether particles is transferred to the matter, thus setting them in vibration. If such action be assumed, the actual density of the ether may be the same in all media, the mathematical expression for the forces will lead to the same equations as those we obtain by supposing that there is a variation of density, and since it is clearly reasonable to suppose that this action between

[1] *Phil. Mag.*, July 1893.

[2] The equations of motion for a medium such as is supposed above can be written—

$\rho\times$ acceleration of ether $+\ \rho'\times$ acceleration of matter $=\Sigma\,\mathrm{B}\times$ function of ether displacements, and their differential coefficients with respect to the coordinates $+\ \Sigma\,\mathrm{B}'\times$ similar function for matter displacements.

The quantity ρ may be spoken of as the effective ether density, the quantities B as the effective elasticity or rigidity.

matter and ether is, in a crystal, a function of the direction of vibration, the apparent or effective density of the ether in such a body will depend on the direction of displacement.

Now these hypotheses will conduct us by strict mathematical reasoning to laws for the propagation, reflexion and refraction, double refraction and polarisation, dispersion, absorption, and anomalous dispersion and aberration of light which are in complete accordance with the most accurate experiments.

The rotatory polarisation of quartz, sugar, and other substances points to a more complicated action between the ether and matter than is contemplated above; and, accordingly, other terms have to be introduced into the equations to account for these effects. It will be noted as a defect, and perhaps a fatal one, that the connection between electricity and light is not hinted at, but I hope to return to that point shortly.

Such a medium as I have described is afforded us by the labile ether of Lord Kelvin. It is an elastic solid or quasi-solid incapable of transmitting normal waves. The quantity A is zero, but Lord Kelvin has shown that the medium would still be stable provided its boundaries are fixed, or, which comes to the same thing, provided it extends to infinity. Such a medium would collapse if it were not held fixed at its boundaries; but if it be held fixed, and if then all points on any closed spherical surface in the medium receive a small normal displacement, so that the matter within the surface is compressed into a smaller volume, there will be no tendency either to aid or to prevent this compression, the medium in its new state will still be in equilibrium, the stresses in any portion of it which remains unaltered in shape are independent of its volume, and are functions only of the rigidity and, implicitly, of the forces which hold the boundary of the whole medium fixed.

A soap film affords in two dimensions an illustration of such a medium; the tension at any point of the film does not depend on the dimensions; we may suppose the film altered in area in any way we please—so long as it remains continuous—without changing the tension. Waves of displacement parallel to the surface of the film would not be transmitted. But such a film in consequence of its tension has an apparent rigidity for displacements normal to its surface: it can transmit transverse waves with a velocity which depends on the tension. Now the labile ether is a medium which has, in three dimensions, characteristics resembling those of the two-dimensional film. Its fundamental property is that the potential energy per unit volume, in an isotropic body, so far as it arises from a given strain, is proportional to the square of the resultant twist. In an incompressible elastic ether this potential energy depends upon the shearing strain. Given such a medium—and there is nothing impossible in its conception—the main phenomena of light follow as a necessary consequence. We have a mechanical theory by the aid of which we can explain the phenomena; we can go a few steps behind the symbols we use in our mathematical processes. Lord Kelvin, again, has shown us how such a medium might be made up of molecules having rotation in such a way that it could not be distinguished from an ordinary fluid in respect to any irrotational motion; it would, however, resist rotational movements with a force proportional to the twist, just the force required; the medium has no real rigidity, but only a quasi-rigidity conferred on it by its rotational motion. The actual periodic displacements of such a medium may constitute light. We may claim, then, with some confidence to have a mechanical theory of light.

But nowadays the ether has other functions to perform, and there is another theory to consider, which at present holds the field. Maxwell's equations of the electromagnetic field are practically identical with those of the quasi-labile ether. The symbols which occur can have an electromagnetic meaning; we speak of permeability and inductive capacity instead of rigidity and density, and take as our variables the electric or magnetic displacements instead of the actual displacement or the rotation.

Still such a theory is not mechanical. Electric force acts on matter charged with electricity, and the ratio of the force to the charge can be measured in mechanical units. A fundamental conception in Maxwell's theory is electric displacement,

and this is proportional to the electric force. Moreover, its convergence measures the quantity of electricity present per unit volume; but we have no certain mechanical conception of electric displacement or quantity of electricity, we have no satisfactory mechanical theory of the electromagnetic field. The first edition of the 'Electricity and Magnetism' appeared twenty years ago. In it Maxwell says: 'It must be carefully borne in mind that we have made only one step in the theory of the action of the medium. We have supposed it to be in a state of stress, but we have not in any way accounted for this stress or explained how it is maintained. This step, however, appears to me to be an important one, as it explains by the action of consecutive parts of the medium phenomena which were formerly supposed to be explicable only by direct action at a distance. I have not been able to make the next step, namely, to account by mechanical considerations for these stresses in the dielectric.' And these words are true still.

But, for all this, I think it may be useful to press the theory of the quasi-labile ether as far as it will go, and endeavour to see what the consequences must be.

The analogy between the equations of the electromagnetic field and those of an elastic solid has been discussed by many writers. In a most interesting paper on the theory of dimensions, read recently before the Physical Society, Mr. Williams has called attention to the fact that two only of these analogies have throughout a simple mechanical interpretation. These two have been developed at some length by Mr. Heaviside in his paper in the 'Electrician' for January 23, 1891. To one of them Lord Kelvin had previously called attention ('Collected Papers,' vol. iii. p. 450.)

Starting with a quasi-labile ether, then, we may suppose that μ, the magnetic permeability of the medium, is $4\pi\rho$,[1] where ρ is the density, and that K, the inductive capacity, is $1/4\pi B$, B being the rigidity, or the quasi-rigidity conferred by the rotation.

The kinetic energy of such a medium is $\frac{1}{2}\rho(\dot{\xi}^2+\dot{\eta}^2+\dot{\zeta}^2)$, where $\dot{\xi}, \dot{\eta}, \dot{\zeta}$ are the components of the displacement. Let us identify this with the electromagnetic energy $(\alpha^2+\beta^2+\gamma^2)8\pi$, α, β, γ being components of the magnetic force, so that $\alpha=\dot{\xi}$, $\beta=\dot{\eta}$, $\gamma=\dot{\zeta}$. Then the components of the electric displacement, assuming them to be zero initially, are given by

$$f=\frac{1}{4\pi}\left(\frac{d\zeta}{dy}-\frac{d\eta}{dz}\right), \text{ \&c.};$$

that is, the electric displacement $\mathfrak{D}$ multiplied by 4π is equal to the rotation in the medium. Denote this by Ω.

The potential energy due to the strain is

$$\tfrac{1}{2}B\Omega^2, \text{ or } \tfrac{1}{2}16\pi^2 B\mathfrak{D}^2,$$

and on substituting for B this becomes

$$\frac{1}{2}\frac{4\pi}{K}\mathfrak{D}^2,$$

which is Maxwell's expression for the electrostatic energy of the field.

Thus so far, but no farther, the analogy is complete; the kinetic energy of the medium measures the magnetic energy, the potential energy measures the electrostatic energy. The stresses in the ether, however, are not those given by Maxwell's theory.

In the other form of the analogy we are to take the inductive capacity as $4\pi\rho$ and the magnetic permeability as $1/4\pi B$. The velocity measures the electric force, and the rotation the magnetic force, so that electrostatic energy is kinetic, and magnetic energy potential. Such an arrangement is not so easy to grasp as the other. Optical experiments, however, show us that in all probability it is ρ, and not B, which varies, while from our electrical measurements we know that K is variable and μ constant; hence this is a reason for adopting the second form.

[1] If we adopted Mr. Heaviside's rational system of units the 4π would disappear.

In either case we look upon the field as the seat of energy distributed per unit of volume according to Maxwell's law. The total energy is obtained by integration throughout the field.

Now we can transform this integral by Green's theorem to a surface integral over the boundary, together with a volume integral through the space; and the form of these integrals shows us that we may look upon the effects, dealing for the present with electrostatics only, as due to the attractions and repulsions of a certain imaginary matter distributed according to a definite law over the boundary and throughout the space. To this imaginary matter, then, in the ordinary theory we give the name of Electricity.

An electrified conducting sphere, according to these analogies, is not a body charged with a quantity of something called electricity, but a surface at which there is a discontinuity in the rotation impressed upon the medium, or in the flow across the surface; for in the conductor a viscous resistance to the motion takes the place of rigidity. No permanent strain can be set up.

From this standpoint we consider electrical force as one of the manifestations of some action between ether and matter. There are certain means by which we can strain the ether: the friction of two dissimilar materials, the chemical action in a cell are two; and when, adopting the first analogy, this straining is of such a nature as to produce a rotational twist in the ether, the bodies round are said to be electrified; the energy of the system is that which would arise from the presence over their surfaces of attracting and repelling matter, attracting or repelling according to the inverse square law. We falsely assign this energy to such attractions instead of to the strains and stresses in the ether.

Such a theory has many difficulties. It is far from being proved; perhaps I have erred in trespassing on your time with it in this crude form. The words of the French *savant*, quoted by Poincaré, will apply to it: 'I can understand all Maxwell except what he means by a charged body.' It is not, of course, the only hypothesis which might be formed to explain the facts, perhaps not even the most probable. For many points the vortex sponge theory is its superior. Still I feel confident that in time we shall come to see that the phenomena of the electromagnetic field may be represented by some such mechanism as has been outlined, and that confidence must be my excuse for having ventured to call your attention to the subject.

The following Reports and Papers were read:—

1. *Interim Report of the Committee on a National Physical Laboratory.* See Reports, p. 120.

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2. *Interim Report of the Committee on Electro-optics.* See Reports, p. 121.

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3. *Report of the Committee on Solar Radiation.*—See Reports, p. 144.

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4. *Report of the Committee for Comparing and Reducing Magnetic Observations.*—See Reports, p. 120.

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5. *Report of the Committee in connection with the Magnetic Work of the Falmouth Observatory.*—See Reports, p. 121.

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6. *On the Period of Vibration of Electrical Disturbances upon the Earth. By* Professor G. F. FitzGerald, *Sc.D., M.A., F.R.S., F.T.C.D.*

Professor J. J. Thomson and Mr. O. Heaviside have calculated the period of vibration on a sphere alone in space and found it about ·059 second. The fact that the upper regions of the atmosphere conduct makes it possible that there is a period of vibration due to the vibrations similar to those on a sphere surrounded by a concentric spherical shell. In calculating this case it is not necessary to consider propagation in time for an approximate result, and it was pointed out that a roughly approximate result could be obtained by equating the electric force at the centre of the earth to a simply harmonic distribution of electricity on its surface and on that of a concentric shell, to the electric force due to the rate of variation of the Vector potential of the electric currents calculated on the assumption of a simply periodic variation of the electric distribution. It appears that the displacement currents between the outer and inner shells are the only contributors to the Vector potential. The value of the time of vibration obtained by this very simple approximation is

$$T = \pi\sqrt{\frac{2K\mu a^2 b^2 \log a/b}{a^2 - b^2}}.$$

Applying this to the case of the earth with a conducting layer at a height of 100 kilometres (much higher than is probable) it appears that a period of vibration of about one second would be possible. A variation in the height of the conducting layer produces only a small effect upon this if the height be small compared with the diameter of the earth. In the case of the sun the period of vibration would be about a hundred times as great. An approximate estimate was made as to the electric density at the pole required to produce a horizontal force at the equator equal to about the hundredth part of the earth's horizontal force, and it was found to be eight electrostatic units per square centimetre. Anything very much greater than this should produce a measurable reduction of barometric pressure. Attention was called to the desirability of having a sufficient number of magnetic stations in a ring round the magnetic pole to be able to determine whether there were simultaneous, easterly or westerly, waves of disturbance of horizontal force. Such a simultaneous disturbance, of which there was some evidence from the present sparsely distributed observatories, would mean that there was an earth current which was running through the earth in such a way that it must be continued by auroral discharges in the upper regions of the air.

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7. *The Moon's Atmosphere and the Kinetic Theory of Gases. By* G. H. Bryan, *M.A.*

[The possibility of applying the kinetic theory of gases to explain the absence of any perceptible atmosphere round the Moon seems to have been contemplated ever since the earliest days of the kinetic theory itself. Mr. S. Tolver Preston claims to have been the first to suggest this explanation ('Nature,' Nov. 7, 1878); but the idea was thought of long before then, for Waterston, in his now well-known paper on 'The Physics of Media' ('Phil. Trans. R.S.,' 1892 [A]), specially considers the problem of the Moon's atmosphere. His investigation would, however, require all the molecules of a gas to have the same velocity, which we now know to be incorrect, and it leads to the conclusion that the existence of a lunar atmosphere would be possible at ordinary temperatures.]

Now, according to the well-known 'error' law of distribution of velocity among the molecules of a gas, there must always be some molecules moving with sufficiently great speeds to overcome the attraction of any body, however powerful, and some whose speed is too small to enable them to escape from the attraction of any body, however feeble. On this assumption no planet would theoretically have an absolutely permanent atmosphere. If, however, the proportion of molecules which escape is relatively exceedingly small, the atmosphere of the planet may be regarded as practically permanent. In order, therefore, to test the relative

degree of permanence of the atmospheres of different celestial bodies, the author has calculated what proportion of the molecules of oxygen and hydrogen at different temperatures have a sufficiently great speed to fly off from the surfaces of, and never return to, the Moon, Mars, and the Earth. The corresponding results for the Sun are also given, not, however, at its surface, but at the Earth's distance from the Sun's centre, where the critical speed is, of course, $\sqrt{2} \times$ the speed of the Earth's orbital motion.

The numbers, which are given in Table I., p. 684, represent, in each case, the average number of molecules, among which there is *one* molecule whose speed exceeds the critical amount. Thus, for oxygen at temperature 0° C. rather over one molecule in every *three billion* is moving fast enough to fly off permanently from the Moon, and only one in every $2 \cdot 3 \times 10^{329}$ is moving fast enough to escape from the Earth's atmosphere, while the Sun's attraction, even at the distance of the Earth, prevents more than one in every 2×10^{1940} from escaping.

Now it is generally stated that at the Earth's surface there are somewhere about 18×10^{18} molecules in a cubic centimetre of air. If we suppose the Moon's surface were invested with an atmosphere, say of oxygen, of this density, every cubic centimetre would contain, roughly, about six million molecules moving with sufficient speed to carry them away from the Moon. But the velocity requisite to overcome the Earth's attraction would only be attained by one molecule in a volume of $1 \cdot 3 \times 10^{310}$ cubic centimetres, that is, in a globe of radius about 2×10^{98} kilometres. In our Earth's atmosphere the acquisition of the requisite speed by a single molecule would only occur once at rare intervals, and would probably be far too rare to affect the permanency of the Earth's atmosphere, even during the long periods of time through which we are wont to trace the history of the solar system.

In the case of Mars the corresponding figure shows that an atmosphere containing oxygen is practically permanent at all ordinary temperatures, but that such an atmosphere could not remain on the planet if its temperature were as high as 819° C.

If the Earth possessed an atmosphere of *hydrogen* at temperature 0° C., containing 10^{18} molecules per cubic centimetre, there would be one molecule in every 60 cubic centimetres whose velocity would be sufficient to carry it away permanently. Remembering that the Earth at one time was much hotter than at present, we see that the absence of hydrogen from the Earth's atmosphere (except in the form of water) is easily accounted for. In the case of the Sun, a hydrogen atmosphere would be permanent at 0° C., even as far off as the Earth, as is shown by the number $2 \cdot 7 \times 10^{307}$. At one-tenth of the Earth's distance from the Sun we should obtain the same number with an absolute temperature ten times as high, *i.e.*, 2730° absolute, or 2457° C., and so on. A considerably higher temperature would, however, be consistent with *permanency*. Thus the kinetic theory quite explains the existence of hydrogen in the Sun's atmosphere at high temperatures.

The present theory seems to preclude the possibility of the Moon ever having had an atmosphere. If the Moon were formerly much hotter than at present the proportion of gaseous molecules tending to fly off would be greater, and such a loss would be exactly the reverse of the process which the nebular hypothesis assumes to be taking place in the solar system.

But it would seem probable that this flying off of gaseous molecules is not an essential condition in explaining the Moon's absence of atmosphere by means of the kinetic theory. It is only necessary to assume the existence of a distribution of matter of excessive tenuity pervading interplanetary space in order to account for a gradual increase taking place in the atmospheres of all the planets, and such an assumption, taken in conjunction with the kinetic theory, is *quite compatible* with the absence of any *perceptible* atmosphere surrounding the Moon, and of any *perceptible* resistance to the motions of the Moon and planets.

The kinetic theory enables us to compare the densities at different points of a mass of gas in equilibrium under such fixed central forces as the attractions of the celestial bodies. If we apply the theory to the system consisting of the Sun, Moon, and Earth, we shall find the relative densities given in Table II., the density

TABLE I.—*Average Number of Molecules of Gas to every one whose Speed is sufficiently great to overcome the Attraction of the Corresponding Body.*

Position relative to attracting body	Hydrogen at 0° C. (=273° absolute) Oxygen at 4095° C. (=4368° absolute)	Hydrogen at −205° C. (=68° absolute) Oxygen at 819° C. (=1092° absolute)	Hydrogen at −246° C. (=17° absolute) Oxygen at 0° C. (=273° absolute)	Hydrogen at −269° C. (=4¼° absolute) Oxygen at −205° C. (=68° absolute)
Moon's surface	$3{\cdot}6$	$610{\cdot}0$	$2{\cdot}7 \times 10^{12}$	$6{\cdot}9 \times 10^{51}$
Surface of Mars	$3920{\cdot}0$	$5{\cdot}0 \times 10^{15}$	$1{\cdot}0 \times 10^{65}$	$1{\cdot}8 \times 10^{263}$
Earth's surface	$6{\cdot}0 \times 10^{19}$	$3{\cdot}3 \times 10^{81}$	$2{\cdot}3 \times 10^{329}$	$4{\cdot}5 \times 10^{1322}$
Earth's atmosphere at a height of eighty miles	$2{\cdot}3 \times 10^{19}$	$7{\cdot}6 \times 10^{79}$	$5{\cdot}7 \times 10^{322}$	$1{\cdot}5 \times 10^{1296}$
Sun at distance of Earth	$2{\cdot}7 \times 10^{307}$	$6{\cdot}6 \times 10^{1233}$	$2{\cdot}0 \times 10^{4940}$	$1{\cdot}7 \times 10^{19767}$

TABLE II.—*Relative Densities of Oxygen and Hydrogen in a Permanent Distribution, taking their Densities at the Earth's Surface as Unity.*

Position relative to attracting body	Hydrogen at 0° C. (=273° absolute) Oxygen at 4095° C. (=4368° absolute)	Hydrogen at −205° C. (=68° absolute) Oxygen at 819° C. (=1092° absolute)	Hydrogen at −246° C. (=17° absolute) Oxygen at 0° C. (=273° absolute)	Hydrogen at −269° C. (=4¼° absolute) Oxygen at −205° C. (=68° absolute)
Earth's surface	$1{\cdot}0$	$1{\cdot}0$	$1{\cdot}0$	$1{\cdot}0$
Earth's atmosphere at a height of eighty miles	$0{\cdot}3859$	$0{\cdot}02268$	$2{\cdot}414 \times 10^{-7}$	$3{\cdot}4 \times 10^{-27}$
Moon's surface	$3{\cdot}1 \times 10^{-20}$	$9{\cdot}4 \times 10^{-79}$	$7{\cdot}7 \times 10^{-313}$	$3{\cdot}5 \times 10^{-1249}$
At Moon's distance from Earth	$4{\cdot}6 \times 10^{-21}$	$4{\cdot}6 \times 10^{-82}$	$4{\cdot}5 \times 10^{-326}$	$4{\cdot}0 \times 10^{-1302}$
At Earth's distance from Sun	$2{\cdot}1 \times 10^{-21}$	$1{\cdot}9 \times 10^{-83}$	$1{\cdot}4 \times 10^{-331}$	$3{\cdot}6 \times 10^{-1324}$
Interstellar space	$2{\cdot}7 \times 10^{-330}$	$4{\cdot}9 \times 10^{-1318}$	$5{\cdot}6 \times 10^{-5724}$	$9{\cdot}9 \times 10^{-21694}$

TABLE III.—*Relative Densities in a Permanent Distribution, taking the Average Densities of Distribution in Interstellar Space as Unity.*

Position relative to attracting body	Hydrogen at 273° absolute Oxygen at 4368° absolute	Hydrogen at 68° absolute Oxygen at 1092° absolute	Hydrogen at 17° absolute Oxygen at 273° absolute	Hydrogen at 4¼° absolute Oxygen at 68° absolute
At infinity	$1{\cdot}0$	$1{\cdot}0$	$1{\cdot}0$	$1{\cdot}0$
At Earth's distance from Sun	$7{\cdot}9 \times 10^{308}$	$3{\cdot}9 \times 10^{1235}$	$2{\cdot}4 \times 10^{4942}$	$3{\cdot}6 \times 10^{19769}$
At Moon's distance from Earth	$1{\cdot}7 \times 10^{309}$	$9{\cdot}4 \times 10^{1236}$	$8{\cdot}0 \times 10^{4947}$	$4{\cdot}0 \times 10^{19791}$
Moon's surface	$1{\cdot}2 \times 10^{310}$	$1{\cdot}9 \times 10^{1246}$	$1{\cdot}4 \times 10^{4961}$	$4{\cdot}2 \times 10^{19844}$
Earth's surface	$3{\cdot}7 \times 10^{329}$	$2{\cdot}0 \times 10^{1317}$	$1{\cdot}8 \times 10^{5273}$	$1{\cdot}0 \times 10^{21093}$

of the corresponding gas in the atmosphere at the Earth's surface being taken as unity. If we take the density at an infinite distance from the Sun to be unity, the corresponding results will be given by Table III.

The assumption on which these results are calculated may be called an 'equilibrium theory,' since it takes no account of the motions of the bodies in question, and it assumes a permanent distribution to have been attained, so that the whole of the gas is at a uniform temperature.

When every allowance is made for the artificial character of the assumptions it is still highly unreasonable to suppose that the Moon could have an atmosphere so far in excess of that required by the equilibrium theory that its presence could be detected even by the most careful observations; and a very few molecules of oxygen and nitrogen flying about in interstellar or interplanetary space would represent a number far in excess of that required by the equilibrium theory, and would therefore tend to augment the total mass of the Earth's atmosphere.

If we try to compare the atmospheres of different planets, such as the Earth and Mars, the 'equilibrium theory' breaks down completely, as is only natural when we remember how rarely a single molecule leaves the atmosphere of either planet.

It is different in the case of two bodies so near each other as the Earth and Moon. Among the molecules of gas which at any time might find themselves in the neighbourhood of the Moon and Earth the greater number would be drawn in by the more attractive body, and the Moon would not, therefore, be likely to obtain an atmosphere like that surrounding the Earth.

At no period has it possessed an atmosphere of oxygen and nitrogen comparable in density with that of the Earth. A decrease of density in a planet's atmosphere could only take place by the condensation in liquid form of vapours present in it, not by matter leaving the planet.

Thus the kinetic theory of gases is capable of accounting for absence of air from the Moon without making any assumptions contradictory to the nebular hypothesis.

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8. *On Grinding and Polishing.* *By* Lord Rayleigh, *Sec.R.S.*

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9. *Simple Apparatus for Observing and Photographing Interference and Diffraction Phenomena.* *By* W. B. Croft, *M.A.*

A wooden screen 16 inches high and 9 inches broad has an opening at a height of 10 inches which will take a spectroscope slit or a thin metal plate with a pinhole: a convex lens focusses sunlight or limelight on the small aperture; a lamp, however, gives sufficient light for the main effects without the finer detail. At about 2 feet distance an A or B Huygens' microscope eyepiece is adjusted so that its field is evenly covered with the light; about 6 inches in front of this is the holder for the diffraction-objects—a stiff-jointed arm about 3 inches long is a convenient adjustment for height. Various things are fixed on 3-inch squares of wood which have a central hole $\frac{3}{4}$ inch square; a slot in the middle of one side of the wood goes over a screw at the end of the jointed arm; a nut clamps it, but allows movement in a vertical plane. The chief simple objects are: Single edge, square corner, double edge, bi-prism, inclined mirrors, needle-eyes, needle-points, needles of various thicknesses, needle with opaque slip on one side, needle with mica slip on one side, perforated zinc, wire gauze, shot cemented on glass for Arago's bright spot at the centre of the shadow of a circular screen, holes of graduated sizes in a metal plate.

If the eyepiece is passed through a collar which will fix on the front of a camera in the place of the ordinary lens, an image is made on the ground glass which can be photographed. The rays emerge parallel and the image varies in size, but remains in focus for all positions of the eyepiece and ground glass.

In illustration of the two modes of observing these phenomena the author drew attention to an old set of diffraction objects, consisting of fifty-nine small geo-

metrical figures on glass. They were intended to be placed in front of a telescope focussed to a distant point of light, according to the plan of Fraunhofer and Schwerd. The result is a system of radiating lines, which consist of spectral images of the point of light; but if the same are viewed as above with the eyepiece alone, the extending spectra mostly disappear, and more elaborate and finely defined central figures are formed.

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10. *On Wilson's Theory respecting the asserted foreshortening of the inner side of the Penumbræ of the Solar Spots when near the Sun's Limb, and of the probable thickness of the Photospheric and the Penumbral Strata of the Solar Envelopes. By* Rev. FREDERICK HOWLETT.

For a considerable portion of the period of upwards of thirty years, during which the author of this paper has maintained a more or less continuous record of the solar spots—during, be it noted, three full successive periods of the maximum, minimum, and intermediate conditions of solar-spot activity, and including some thousands of careful and roughly micrometric observations—one point has not a little excited his surprise, viz., to have scarcely in *any one* undoubted instance been able to verify the observation first made by Dr. Wilson, Professor of Practical Astronomy in the University of Glasgow, as long ago as the months of November and December 1769, as well as on, he affirms, many subsequent occasions.

The phenomena in question which Wilson claims to have frequently seen is, in brief, this, that if a spot, when well on the disk, has its penumbra equally distributed on all sides of the umbra, the effects of foreshortening on the sphere, in consequence of the funnel-shaped nature of a spot, will be that whenever a spot is near the limb the side of the penumbra nearest to the sun's centre will be extremely foreshortened, and that when very near the limb, not only the whole of the inner side of the penumbra, but the whole of the umbra itself, will become invisible, the outermost side of the penumbra alone remaining in sight.

Wilson tells us (as recorded in the 'Philosophical Transactions' for 1774) that he effected his observations by direct vision, using a small, and he says an excellent, Gregorian reflecting telescope of 26 inches focal length, with a magnifying power of 112 linear.

The author's observations were made by projecting the sun's image on a large screen nearly 5 feet by 4 feet, using a small but excellent refractor by the elder Dollond of 3 inches aperture with 46 inches focal length, with magnifying powers of from 80 to 200 times linear.

When using power 80, with the screen placed 4 feet 3 inches from the eyepiece, the projected image of the sun has a diameter of 32 inches, so that, consequently, each inch of the image is equivalent to just about 60″ of celestial arc, and which is the scale on which the author's drawings are usually made. A sort of micrometer, moreover, consisting of a small disk of glass ruled off into the two-hundredths of an inch, is placed in the focus of the eyepiece, so that the divisions on the glass disk are distinctly seen projected also on the screen, each exactly half an inch apart.

When a power of 200 linear is used the sun's image is seen 6 feet 4 inches in diameter on the screen when placed at the same distance from the eyepiece as before mentioned, and when each minute of arc thereon measures $2\frac{1}{2}$ inches, so that, in fact, in such enlarged images seconds of arc can be readily measured by a pair of common dividers.

Now as regards Wilson's observations—with which the author professes himself to be most strongly at issue, especially when spots of any considerable magnitude are concerned—nothing could be stated in a more exact, cautious, and circumstantial manner. And it is, in all probability, in consequence of this that the phenomena Wilson claims to have seen have been handed down as facts (without their having been adequately verified or disproved) in almost all works on physical astronomy to the present day.

The author, however, had the honour of calling the special attention of astro-

nomers to the point in question in a paper read before the Royal Astronomical Society in June, 1886, soon after which Mr. Cowper Ranyard, the late Mr. Whipple of the Kew Observatory, and the late Father Perry of Stonyhurst, expressed themselves in close agreement on the whole with the author, the two former emphatically so; as also, quite lately, has Father Sidgreaves, Director of the last-mentioned observatory.

Professor Spörer, also, of Munich, in a copious *résumé* of his labours in connection with the solar spots (read at Geneva in August, 1885) denies that the spots possess the character of funnels (*tonnoirs*) so commonly attributed to them.

Not, however, that the statements of Wilson at the time when they were brought forward remained unchallenged. For not only did the Rev. Francis Wollaston (father of the great chemist) demur to them, but the great mathematician and observer De la Lande (as recorded in the French Academy 'Memoirs' for 1776) admitted that whilst some spots behaved as Wilson states, yet that the rule by no means always held good. Wilson's spot, moreover, of November, 1769, had so large a size as a length and breadth of one minute of arc, and he states that the effects of foreshortening even in a spot of such extensive dimensions was to cause the central umbra to completely disappear when about 24″ from the limb, whilst the side of the penumbra nearest the limb still continued to be eminently conspicuous, which would necessitate, of course, a very large amount of depth and of shelving indeed! The author of this paper, however, can only say that in repeated observations he has never found any of this asserted foreshortening, nor consequent apparent relative displacement of the umbra, when spots of the above-mentioned size have been no more than 20″, 15″, or even 5″ from the limb. The author does not wish to affirm that no measure whatever of the foreshortening ever occurs, but he emphatically affirms that where it does it is only in the *very slightest degree*, though it necessarily is somewhat more apparent in very small spots.

All these appearances can be readily exhibited on a globe of a foot or so in diameter, in which depressions have been worked of various sizes and various depths; and from which it will at once be seen how very shallow must be the spots which admit of the umbra remaining apparently *central* in the midst of the penumbra, when so near the limb as has just been mentioned.

Such, then, is the experience of the author of this paper, who also would wish to state that in the present year he requested leave (and was most courteously permitted) to compare his hand-drawings of the sun for the last ten years—embracing two maximum and one minimum period of solar spot activity—with the photographic record at the Royal Observatory at Greenwich; and when, as far as could be perceived by means of a magnifying lens, his contention was found to hold good in every instance in which the concurrent dates of observation admitted of such a comparison, as was allowed by both Mr. Hollist and another junior member of the assistants, who aided in the investigation.

The appearance of a spot may, occasionally, seem to militate against the author's views, and strongly to favour Wilson's, but, as Mr. Turner, chief assistant at Greenwich, wrote him lately, 'the *history* of a spot needs studying.' And this is very essential, because, on various occasions, a spot which when *near* the limb seemed to favour Wilson was found not to do so when further from the limb, when it was plainly evident that the umbra was *not central.*

The results, finally, of the author's protracted observations and measurements lead him to the conclusion that both the photospheric and also penumbral envelopes of the sun are comparatively extremely shallow, and that the photosphere consists of one layer only of the so-called 'rice-grain' entities, lying in close contiguity to the subjacent penumbra, and at most not more than the $\frac{1}{425}$th part of the sun's radius, or, say, about one thousand miles in thickness, and that the penumbral stratum is but little, if any, thicker; otherwise the umbra could not remain *plainly central* within the penumbra (as it almost always does) when the latter is no more than ten, or even five, seconds from the sun's limb.

FRIDAY, SEPTEMBER 15.

The following Papers were read:—

1. *Report on the Present State of our Knowledge of Electrolysis and Electro-chemistry. By* W. N. SHAW, *F.R.S., and the* Rev. T. C. FITZPATRICK.—See Reports, p. 146.

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2. *On the Connection between Ether and Matter.*
By DR. OLIVER J. LODGE, *F.R.S.*

The author reported progress in his experiments to examine into the connection between ether and matter, and concludes that at least unless matter is electrified there is no stress-connection between these two bodies of a kind to interfere with their relative motion.

From this he draws several conclusions, one of which is that radiation is due to the motion of electrified parts of molecules—not to the molecule as a whole.

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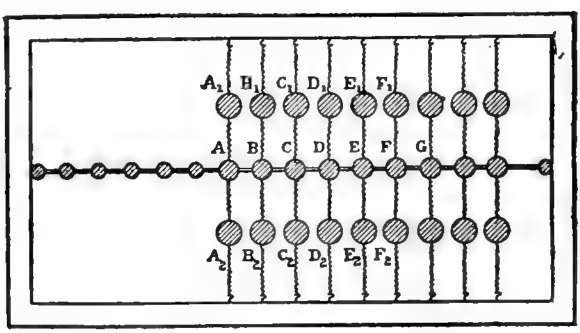
3. *On a Mechanical Analogue of Anomalous Dispersion.*
By R. T. GLAZEBROOK, *M.A., F.R.S.*

In the figure A, B, C represent a series of particles, each of mass m, connected together by strings of length a. The particles can vibrate on the plane of the paper, and a wave of simple harmonic vibration will travel along them with definite velocity. The tension in the string is F. Each particle is connected as



shown by two springs to two masses A_1, A_2; B_1, B_2, &c., respectively, the masses of these particles being M. This second series of particles is connected by springs to the sides of the frame. The period of vibration of one of the particles, such as A, when the string joining it to the particles on either side is cut and the masses A_1, A_2 are held fixed, is t_0; the period of vibration of a particle such as A_1 under the action of the spring joining it to the frame alone is T_0. The string joining the particles A, B, C is continued, and carries a series of particles each of mass m_0 unconnected to any springs. Suppose a wave of period T to be travelling with velocity V_0 along this string; on reaching the particle A the velocity becomes V, and it can be shown that

$$\frac{V_0^2}{V^2}=\frac{m}{m_0}\left\{1-\frac{T^2}{t_0^2}+\frac{m}{M}\frac{T^4}{t_0^4}\frac{T_0^2}{T^2-T_0^2}\right\}=\mu^2 \text{ say.}$$

Suppose now that t_0 is large, and let T be less than t_0 but greater than T_0; suppose also that m is greater than m_0. Then μ^2 is greater than unity; a wave travels along A, B, C, but with less velocity than along the external row of

particles. As T decreases to T_0, μ^2 increases—*i.e.*, the velocity decreases—until when $T=T_0$, μ^2 is infinite and V zero. There is an absorption of energy, and below this absorption band the velocity is very small and the refraction is abnormally large. When T is slightly less than T_0, μ^2 is negative, the medium has the properties of a metal; but as T decreases further μ^2 becomes positive, though less than unity. The velocity in the medium is greater than that outside.

Thus the system has all the properties of a medium showing anomalous dispersion.

By a simple transformation the equation for μ^2 can be put into the form

$$\mu^2=\frac{m}{m_0}\left\{1+\frac{m}{M}\frac{T_0^4}{t_0^4}-\frac{T^2}{t_0^2}\left(1-\frac{m}{M}\frac{T_0^2}{t_0^2}\right)+\frac{m}{M}\frac{T_0^4}{t_0^4}\frac{T_0^2}{T^2-T_0^2}\right\}=a^2-k^2\lambda^2+\frac{D\lambda_0^2}{\lambda^2-\lambda_0^2},$$

where λ, λ_0 are the wave-lengths in air of waves of periods T and T_0; this equation has been verified for light by S. P. Langley over a long range of period. For a transparent medium t_0 and T_0 lie outside the limits of the visible spectrum.

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4. *Note on Professor Ebert's Estimate of the Radiating Power of an Atom, with Remarks on Vibrating Systems giving Special Series of Overtones like those Given Out by some Molecules. By* Professor G. F. FITZGERALD, *M.A., F.R.S.*

Attention was drawn to Professor Ebert's paper in 'Wiedemann's Annalen' for 1893, in which he estimated that the energy radiated by a sodium atom as determined by Professor E. Wiedemann was approximately the same as that calculated from Hertz's equation for the radiation from one of his oscillators, if the oscillator be supposed of the diameter of the atom and electrical charge be the ionic charge and the time of vibration the period of the sodium line.

It was pointed out that the period of vibration of a simple oscillator of the size of an atom would be very many times more frequent than that of the sodium line, and that as the energy radiation increases inversely as the cube of the wave-length it follows that the radiation of a simple Hertzian oscillator of the size of an atom might be many thousands of times as great as what Wiedemann has found to be the radiating power of a sodium atom. It follows that sodium atoms must be complex Hertzian oscillators if they are Hertzian oscillators at all, and if they be complex ones their radiating power might be either greater or less than that of a Hertzian; so that Professor Ebert's calculation only shows that *if* an atom be a Hertzian oscillator its radiating power is approximately what he has calculated. It was explained that the fact that the vibration-frequencies of molecules were within the range of frequencies that might be expected if the molecules are systems of the size they are known to be, and of a rigidity about that of ordinary rigid bodies, made it appear that the rigidity of hard bodies may be principally the rigidity of the molecules of which they are composed. The fact that crystalline structure is generally attributed to a peculiarity in the shapes of the molecules, and that deformation confers a crystalline structure on solids, tends to the conclusion that the molecules are deformed by strain. It is otherwise not easy to see why the light-frequencies are so nearly those that might be expected from rigid bodies of the size of the molecules.

In connection with the question of the vibrations of molecules, it is to be observed that vibrating systems in which the motion can be very simply specified may produce extremely complex systems of lines, as is evident to anybody who has tried to express an algebraic function in a Fourier series. A finite series of discrete lines may be produced by supposing a finite vibrator to divide itself into loops and nodes. If the vibrator be of such a structure that, as in an air column, the velocity of propagation of a wave is independent of the wave-length, then the system of overtones will be a system of harmonics. But if the velocity of propagation be any other function of the wave-length, say $V=f(\lambda)$, then it is easy to see

that the frequency of vibration (N) corresponding to n nodes in the length L will be

$$N = \frac{n}{L} f\left(\frac{L}{n}\right).$$

For instance, in a trough of deep water, when $V \propto \sqrt{\lambda}$

$$N \propto \sqrt{n}.$$

An example of a system with a remarkable relation between the velocity of propagation and the wave-length is the case of a system of magnets with their poles close to one another when disturbed to an amount small compared with the distance apart of the poles. In this case the force of restitution is proportional to the *sum* of the angular displacements of contiguous magnets, and it appears that the velocity of propagation of a disturbance is given by

$$V = 2N_0\lambda \cos \frac{\pi l}{\lambda},$$

when λ is the wave-length of the disturbance. This case is interesting in connection with Professor Ewing's theory of the nature of magnets, and it follows that the rate of progression that might be expected of this kind of disturbance in a real magnet would be extremely slow unless the period of vibration approximated to 10^9 per second. The rate of propagation of energy into the system is, however, *very* much more rapid, and might be about 200 to 300 centimetres per second. In a finite system of such magnets the system of overtones is given by

$$N = 2N_0 \cos \frac{n\pi l}{L},$$

which is evidently represented by a series of lines coming up to an edge which is so characteristic of many spectra.

Vibrating linear systems having any desired relation out of a very great number of different relations connecting the velocity of propagation of a wave and the wave-length may be constructed by connecting a system of equidistant wheels by means of indiarubber bands or elastic friction wheels, the latter case being somewhat similar to the case of the magnets already considered. By connecting the wheels each with its next neighbour we get the simplest system. If to this be superposed a system of connection of each with its next neighbour but one, and then each with its next neighbour but two, and so on, complex systems with very various relations between wave-length and velocity can be constructed depending on the relative strengths of the bands employed. These systems would be somewhat analogous to systems of particles connected by laws of force varying in a complex way with the distance apart of the particles. In the case of the bands, &c., the general form of the relation between the velocity and wave-length is

$$V^2 = k_1 \sin^2 \frac{\pi l}{\lambda} + k_2 \sin^2 \frac{2\pi l}{\lambda} + k_3 \sin^2 \frac{3\pi l}{\lambda} + \quad \ldots\ldots$$

which can be varied in a very great number of ways by a proper choice of k_1, k_2, &c.

It was pointed out how a model such as that described by Mr. Glazebrook for illustrating anomalous dispersion could be modified so as to produce almost any desired system of overtones.

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5. *On the Reflection of Sound or Light from a Corrugated Surface.* *By* Lord RAYLEIGH.

The angle of incidence is supposed to be zero, and the amplitude of the incident wave to be unity. If then

$$\zeta = c \cos px \quad \ldots\ldots\ldots\ldots \quad (1)$$

be the equation of the surface, the problem of reflection is readily solved so long as p in (1) is small relatively to k or $2\pi/\lambda$; that is, so long as the wave-length of the corrugation is large in comparison with that of the vibrations. The solution assumes a specially simple form when the second medium is impenetrable, so that the whole energy is thrown back either in the perpendicularly reflected wave or in the lateral spectra. Of this two cases are notable: (a) when—in the application to sound—the second medium is gaseous and devoid of inertia, as in the theory of the 'open ends' of organ-pipes. The amplitude A_0 of the perpendicularly reflected wave, so far as the fourth power of p/k inclusive, is then given by

$$-A_0 = J_0(2kc) + \frac{p^2}{k^2}\cdot\tfrac{1}{2}kc\,J_1(2kc) + \frac{p^4}{k^4}\left\{\tfrac{1}{8}kc\,J_1(2kc) - \tfrac{1}{2}k^2c^2J_2(2kc)\right\} \quad . \quad (2)$$

in which there is no limitation upon the value of kc, so that the corrugation may be as *deep* as we please in relation to λ. If p be very small, the result—viz., $-J_0(2kc)$—is the same as would be obtained by the methods usual in Optics; and it appears that these methods cease to be available when p cannot be neglected.

The second case (β) arises when sound is reflected from a rigid and fixed wall. We find, as far as p^2/k^2,

$$A_0 = J_0(2kc) - \frac{p^2}{2k^2}\,.\,kc\,.\,J_1(2kc) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

If p, instead of being relatively small, exceeds k in magnitude, there are no lateral spectra in the reflected vibrations; and if the second medium is impenetrable, the regular reflection is necessarily total. It thus appears that an extremely rough wall reflects sounds of medium pitch as well as if it were mathematically smooth.

The question arises whether, when the second medium is not impenetrable, the regular reflection from a rough wall ($p>k$) is the same as if $c=0$. Reasons are given for concluding that the answer should be in the negative.

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6. *On the Piezo-electric Property of Quartz.* *By* Lord Kelvin, *Pres.R.S.*[1]

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7. *On a Piezo-electric Pile.* *By* Lord Kelvin, *Pres.R.S.*

The application of pressure to a voltaic pile, dry or wet, has been suggested as an illustration of the piezo-electric properties of crystals, but no very satisfactory results have hitherto been obtained, whether by experiment or by theoretical considerations, so far as I know. Whatever effects of pressure have been observed have depended upon complex actions on the moist, or semi-moist, substances between the metals and electrolytic or semi-electrolytic and semi-metallic conductances of the substances. Clearing away everything but air from between the opposed metallic surfaces of different quality, I have made the piezo-electric pile which accompanies this communication. It consists of twenty-four double plates, each 8 centimetres square, of zinc and copper soldered together, zinc on one side and copper on the other. Half a square centimetre is cut from each corner of each zinc plate, so that the copper square is left uncovered by the zinc at each of its four corners. Thus each plate presents on one side an uninterrupted copper surface, and on the other side a zinc surface, except the four uncovered half square centimetres of copper. A pile of these plates is made, resting one over the other on four small pieces of indiarubber at the four copper corners. The air-space between the opposed zinc and copper surfaces may be of any thickness from half a millimetre to 3 or 4 millimetres. Care must be taken that there are no minute shreds of fibre or dust bridging the air-space. In this respect so small an air-space as half a millimetre gives trouble, but with 3 or 4 millimetres no trouble is found.

[1] Published in the *Philosophical Magazine*, October 1893, pp. 331–342.

The lowest and uppermost plates are connected by fine wires to the two pairs of quadrants of my quadrant electrometer, and it is generally convenient to allow the lowest to lie uninsulated on an ordinary table and to connect it metallically with the outer case of the electrometer.

To make an experiment, (1) connect the two fine wires metallically, and let the electrometer needle settle to its metallic zero.

(2) Break the connection between the two fine wires, and let a weight of a few decigrammes or kilogrammes fall from a height of a few millimetres above the upper plate and rest on this plate. A startlingly great deflection of the electrometer needle is produced. The insulation of the indiarubber supports and of the quadrants in the electrometer ought to be so good as to allow the needle to come to rest, and the steady deflection to be observed, before there is any considerable loss. If, for example, the plates are placed with their zinc faces up, the application of the weight causes positive electricity to come from the lower face of the uppermost plate, and to deposit itself over the upper surface of plate and weight, and on the electrode and pair of quadrants connected with it.

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8. *Electrical Interference Phenomena somewhat Analogous to Newton's Rings, but exhibited by Waves in Wires.* *By* EDWIN H. BARTON, *B.Sc.*

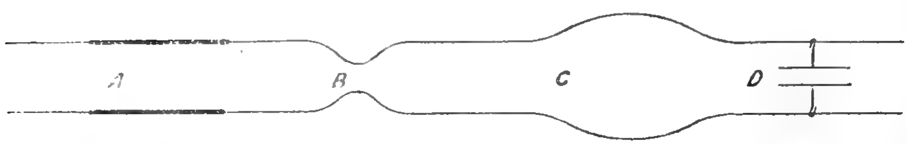
Herr von Geitler,[1] while experimenting in 1892 with electrical waves passing along a pair of long parallel wires, noticed the following phenomena:—

If the wires at any part of their length were either

(1) replaced by others thicker or thinner than the normal wires, as shown at A, fig. 1, or

(2) arranged nearer together or farther apart than their normal distance, as shown at B and C, fig. 1, then, in any of these cases, a partial reflection of the electrical waves occurred at such place of change in the wires.

FIG. 1.—Arrangements which produce partial reflection.



Von Geitler then made further observations of what occurred when a condenser was attached at a *single* point of each wire, as at D, fig. 1, but did not *quantitatively* examine the reflections of the waves produced by the changes first named. This I commenced to do, as it seemed interesting to ascertain if theory and experiment agreed quantitatively. Now it is easy to see that with a finite length of the altered or *abnormal* part of the wires we should have *not a single* reflection merely, but *two* places at which reflections would occur, namely, the beginning and the end of this abnormal part. I thus anticipated that interference phenomena would occur, and that if the length of the abnormal part were gradually increased, the intensity of the transmitted waves would periodically increase and decrease.

The best arrangement which I have obtained for observing these interference effects is that diagramatically shown in fig. 2.

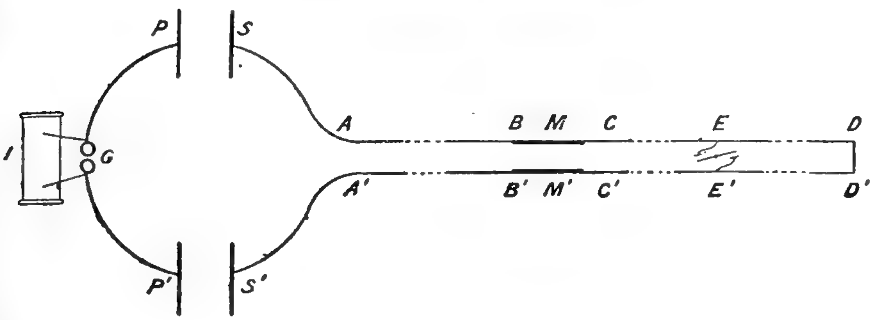
Explanation of Fig. 2.

I. Induction coil worked by two secondary cells.
G. Spark gap.
PG P′. Primary oscillator which emits waves 9 m. long.
GP = GP′ = 1 m. long.
PP′. Discs of zinc plates 40 cm. diameter.

[1] *Wied. Ann.*, vol. 49, 1893, pp. 184–195; *Ueber Reflexion elektrischer Drahtwellen*, von J. Ritter von Geitler.

SS′. Similar discs 30 cm. distant from the former.
SADS′A′D′. The wires along which the electrical waves are propagated.
BCB′C′. The *abnormal* part of the wires.
M. Middle point of same.
SAM = 101 m.
MD = 63 m.
EE′. Electrometer, situated a quarter-wave length from—
DD′, the bridge forming the end of the wires.
AA′ = EE′ = DD′ = 8 cm.

FIG. 2.—Diagram of apparatus.

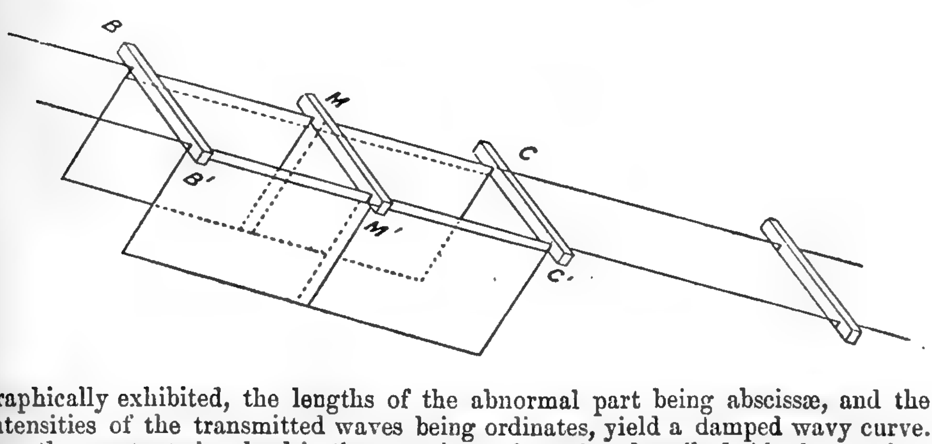


The needle of the electrometer is uncharged, and therefore turns in the same direction whether E or E′ is positive, and is thus able to give a deflection undisturbed by the high frequency used, viz., about 33 million per second.

Although the interference phenomena under consideration are essentially analogous to those of light in thin plates, yet the mathematical theory of the latter will not suffice for our case. Because in the optical phenomena the amplitude of the incident light may be assumed constant, whereas in the electrical analogue the primary oscillator emits waves each of which is feebler than its predecessor. It thus induces in the long wires a continually diminishing series of waves which advance along the wires in the form of a damped train with its large end leading.

I have already published an elementary mathematical theory[1] dealing with the interference phenomena of such a wave train. The results of this theory when

FIG. 3.—Enlarged view of the 'abnormal part' of the wires.



graphically exhibited, the lengths of the abnormal part being abscissæ, and the intensities of the transmitted waves being ordinates, yield a damped wavy curve. For the constants involved in the experiment hereafter described this theory gives

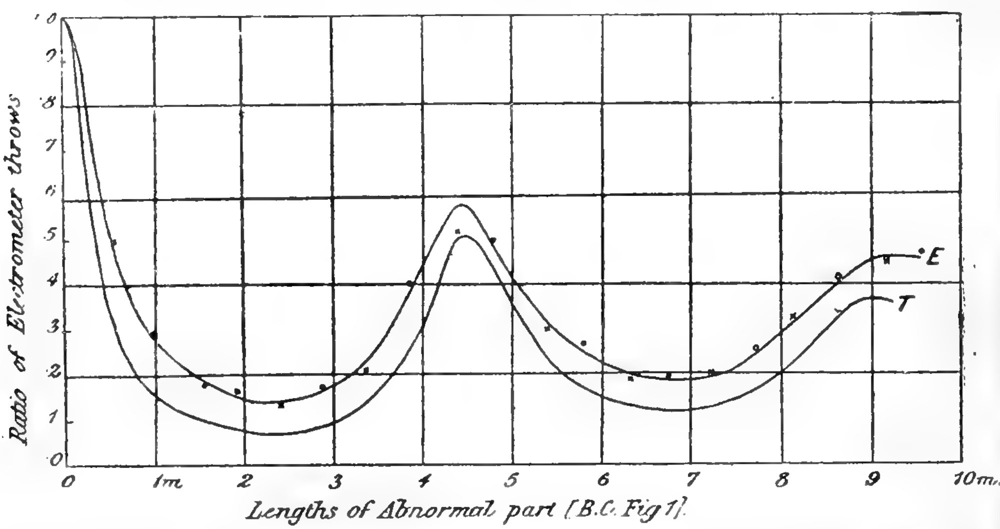
[1] *Proc. Roy. Soc.*, vol. 54, 1893, p. 96.

the curve shown by T, fig. 4. It is thus seen that the lengths of the abnormal parts which give maxima and minima are the same as in the corresponding optical phenomena, but that the values of these maxima and minima, instead of being respectively equal, as in optics, form a damped series fading away to a common steady value.

These interference phenomena may, of course, be experimentally obtained by any of the changes in the wires which produce reflection. But the most striking method which I have found is that of hanging sheets of tin foil upon the conducting wires so as to form the abnormal part, as shown in fig. 3. The sheets of tin foil were 32 cm. deep, the cross-pieces used for separating the wires and sheets were of wood.

The *beginning* of the abnormal part thus formed reflected a wave whose amplitude is of the order 0·8 of that incident upon it. With this arrangement upwards of 200 electrometer readings were taken, the final result of which is shown by the upper curve marked E in fig. 4, the lengths of the abnormal parts being abscissæ and the intensities of the transmitted waves ordinates. It is noticeable that in fig. 4 the theoretical curve lies wholly below the experimental one. The discrepancy, however, is no greater than can be accounted for by a known disturbance which I have already measured, but have not yet succeeded in eliminating. The explanation of this, together with an account of other experiments, I hope to give in a future paper.

FIG. 4.—Energy of transmitted waves.



The above work was carried out in the University of Bonn under the direction of Prof. Hertz, whose invaluable advice I wish most heartily to acknowledge.

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9. *On Interference Phenomena exhibited by the Passage of Electric Waves through Layers of Electrolyte.*[1] *By* G. UDNY YULE.

This research was begun by the author with a view to try and definitely answer the question whether electrolytes possess for rapid electric oscillations the same resistance as for steady currents. Some attempts were first made to directly improve the procedure used in 1889 by Prof. J. J. Thomson,[2] but the results were unsatisfactory, and the following method, by which it was hoped absolute measurements might be obtained, was finally adopted:—

The electric waves (wave-length 9 metres) were propagated between a pair

[1] Published in *Phil. Mag.*, xxxvi. (1893), pp. 531–545.
[2] *Proc. Roy. Soc.*, xlv. 1889, p. 269.

of long copper wires spanned 6 centimetres apart. A short length of these wires was then immersed in an electrolyte, and the intensities of the transmitted wave trains for several different thicknesses of the electrolyte layer compared by an electrometer. If the altered intensity of the wave train were due solely to absorption in the conducting layer, it would be easy from such data to calculate the conductivity of the solution.

The matter proved, however, to be not so simple. The transmitted intensity did not regularly decrease, but varied periodically. The effect was obviously analogous to, or rather identical with, the interference phenomena of thin plates. The transmitted ray is a minimum for a plate a quarter wave-length thick, a maximum for a plate a half wave-length thick, &c.

Owing to this, and a further experimental complication arising from the multiple reflection of waves between every pair of reflecting points on the circuit, the method became too complex to permit of calculating the conductivity of the solution, but the phenomenon retained sufficient intrinsic interest to warrant more complete investigation. Curves showing the transmitted intensity as the thickness of the layer was increased were determined for water, dilute solutions of zinc sulphate, 95 per cent. alcohol, and a mixture of alcohol and water. In all cases the first maximum is very well marked. As this first maximum gives us the half wave-length in the liquid, the method can be used for determining dielectric constants. The following table gives those thus determined for the liquids mentioned above:—

Distilled water	69·5	95 per cent. alcohol . . .	26·7
(1) $ZnSO_4$ solution . . .	72·0	3 volumes 95 per cent. alcohol 1 volume water	34·1
(2) „ „	74·9		

The figures for water and alcohol, though rather low, agree approximately with those found by previous investigators; and the experiments with zinc sulphate solutions confirm Cohn's result,[1] that an addition of salt which largely affects the conductivity of a solution only slightly increases its dielectric constant.

An attempt was finally made to determine the constants of common salt and of soda crystals, but owing to the disturbance of the multiple reflections noted above scarcely any interference effects were noticeable. This shows, however, that the constants for these materials approximate more to normal values than the very high figures found for water and alcohol.

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10. *On a Familiar Type of Caustic Curves.* *By* J. Larmor, *F.R.S.*

The illustration of the formation of caustics by the reflection of the light of the sun or other point-source from a band of polished metal is in everyday use. But it seems worth while to call attention to the fact that obliquity of the incidence on a cylindrical reflector does not vitiate the experiment as an exact representation of the geometrical caustic. The bright caustic surface formed by reflection from a cylinder is, in fact, always itself cylindrical; and the caustic curve depicted on any screen placed across it is merely the section of this cylinder formed by the screen. Although, once this proposition is propounded, its reason is plain, yet it does not seem to have occurred to any of the writers on optics.

It may be shown, also, that when the reflector is a piece of a conical surface the caustic surface is always a conical surface with the same vertex—thus suggesting an extension of the theory of actual caustics into spherical geometry, or rather realising in actuality the analogous theory in spherical geometry. More generally, when the reflector is such as may be bent flat without stretching, *i.e.*, when it is a piece of a developable surface, the caustic surface is one of the same kind, and a geometrical correlation may be established between them.

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[1] *Wied. Ann.*, xlv. 1892, p. 370.

SATURDAY, SEPTEMBER 16.

The following Reports and Papers were read:—

1. *Report of the Committee on Mathematical Tables.*—See Reports, p. 227.

2. *Report of the Committee on the Pellian Equation.*—See Reports, p. 73.

3. *On a Spherical Vortex. By* M. J. M. Hill, *M.A., D.Sc., Professor of Mathematics at University College, London.*

In a paper by the author published in the 'Philosophical Transactions of the Royal Society' in 1884, on the Motion of Fluid, part of which is moving rotationally and part irrotationally, a certain case of motion symmetrical with regard to an axis was noticed.

Taking the axis of symmetry as the axis of z, and the distance of any point from it as r, it was shown that the surfaces

$$ar^2(z-Z)^2+b(r^2-\tfrac{1}{2}c^2)^2=\text{const.},$$

where a, b, c are fixed constants, Z any arbitrary function of the time, contain always the same particles of fluid in a possible case of motion.

If the constant be less than $\frac{1}{4}bc^4$ these surfaces are rings.

The author has not succeeded in determining an irrotational motion on one side of any of these surfaces continuous with the rotational motion on the other side, except in the particular case in which $b=a$, and the constant on the right-hand side $=\frac{1}{4}bc^4$.

The object of this paper is to discuss this case.

In it the surface containing the same particles of fluid breaks up into the evanescent cylinder

$$r^2=0,$$

and the sphere

$$r^2+(z-Z)^2=c^2.$$

The molecular rotation is given by $2\omega=10ar$, so that the molecular rotation along the axis vanishes, and therefore the vortex sphere still possesses the character of a vortex ring.

The irrotational motion outside a sphere moving in a straight line is known, and it is shown in this paper that it will be continuous with the rotational motion inside the sphere provided a certain relation be satisfied.

This relation may be expressed thus:—

The cyclic constant of the spherical vortex is five times the product of the radius of the sphere and the uniform velocity with which the vortex sphere moves along its axis.

The analytic expression of the same relation is

$$4ac^2=3\dot{Z}.$$

This makes

$$2\omega=15\dot{Z}r/(2c^2).$$

All the particulars of the motion are placed together in the following table.

The notation employed is as follows:—

If the velocity parallel to the axis of r be τ, and the velocity parallel to the axis of z be w, then the molecular rotation is given by

$$2\omega=\frac{d\tau}{dz}-\frac{dw}{dr}.$$

Also p is the pressure, ρ the density, and V the potential of the impressed forces.

The motion of the Spherical Vortex $r^2+(z-Z)^2=c^2$ in an infinite mass of fluid parallel to the axis of z with uniform velocity $\dot{Z}$.

—	Rotational Motion inside Sphere	At the Surface of the Sphere	Irrotational Motion outside Sphere
Velocity parallel to axis of r	$3\dot{Z}r(z-Z)/(2c^2)$	$\frac{3}{2}\dot{Z}\sin\theta\cos\theta$	$3c^3\dot{Z}r(z-Z)/(2R^5)$
Velocity parallel to axis of z	$\dot{Z}\{5c^2-3(z-Z)^2-6r^2\}/(2c^2)$	$\dot{Z}(1-\frac{3}{2}\sin^2\theta)$	$c^3\dot{Z}\{3(z-Z)^2-R^2\}/(2R^5)$
$\frac{p}{\rho}+V-\frac{\Pi}{\rho}$	$9\dot{Z}^2\left[\left(r^2-\frac{c^2}{2}\right)^2-\{(z-Z)^2-c^2\}^2+c^4\right]/(8c^4)$	$\frac{9}{8}\dot{Z}^2\cos^2\theta+\frac{9}{32}\dot{Z}^2$	$\frac{1}{8}\dot{Z}^2\left[\left\{5-4\left(\frac{c}{R}\right)^3-\left(\frac{c}{R}\right)^6\right\}+3\cos^2\theta\left\{4\left(\frac{c}{R}\right)^3-\left(\frac{c}{R}\right)^6\right\}+\frac{9}{4}\right]$
Current Function	$3\dot{Z}r^2\{R^2-\frac{5}{3}c^2\}/(4c^2)$	. . . . .	$-c^3\dot{Z}r^2/(2R^3)$
Surfaces containing the same particles of fluid throughout the motion	$3\dot{Z}r^2\{R^2-c^2\}/(4c^2)=\text{constant}$	. . . . .	$\dot{Z}r^2(R^3-c^3)/(2R^3)=\text{constant}$
Velocity potential	. . . . .	. . . . .	$-c^3\dot{Z}(z-Z)/(2R^3)$
Molecular Rotation	$15\dot{Z}r/(4c^2)$	. . . . .	. . . . .
Cyclic Constant of Vortex	$5c\dot{Z}$	. . . . .	. . . . .

The minimum value of $\frac{p}{\rho} + V$ is $\frac{\Pi}{\rho}$, where $\frac{\Pi}{\rho}$ must be determined from the initial conditions.

Further R, θ are such that

$$r = R \sin \theta,$$
$$z - Z = R \cos \theta.$$

The whole motion depends on the following constants:—

(1) The radius of the sphere c.

(2) The uniform velocity $\dot{Z}$.

(3) The minimum value of $\frac{p}{\rho} + V$, viz., $\frac{\Pi}{\rho}$.

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4. *On the Magnetic Shielding of Two Concentric Spherical Shells. By* A. W. Rücker, *F.R.S.*

The formulæ were found which express the shielding of two concentric permeable spherical shells, and several special cases were discussed. The result was reached that if the smallest and largest radii and the volume of the permeable matter are given, the shielding is a maximum for a given portion of the empty shell. If the magnetic field is produced by a small magnet placed at the common centre of the shells, if the empty space is small and the matter highly permeable, the best position is that in which the volume enclosed by the 'crack' is the harmonic mean of the volumes included by the outermost and innermost surface.

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5. *On the Equations for Calculating the Shielding of a Long Iron Tube on an Internal Magnetic Pole. By* Professor G. F. FitzGerald, *M.A., F.R.S.*

Attention was called to the desirability of having the integrals of the form $\int \frac{\cos u \, du}{\sqrt{p^2 + u^2}}$ plotted or tabulated, as it would very much facilitate the calculation of this and other cases to which Bessel's functions were applicable but were complicated in application.

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6. *On the Equations for Calculating the Effect of a Hertzian Oscillator on Points in its Neighbourhood. By* Professor G. F. FitzGerald, *M.A., F.R.S.*

Attention was recalled to the error made by Maxwell when he assumes that for variable electrification it is legitimate to assume that $\Delta^2\psi = 0$ at points of space where there was no electrification. The true expression is $\Delta^2\psi = K\mu \,.\, \ddot{\psi}$. The evaluation of the integrals $\int \frac{\cos u \, du}{\sqrt{p^2 + u^2}}$ was also advocated in order to facilitate the calculation of the effects of a linear Hertzian vibrator on points in its neighbourhood. The elliptic motion of the electric force in the neighbourhood of such an oscillator follows at once from the fact that the vector potential is parallel to the oscillator, and may be taken as $A = iF$. From this we get that the magnetic force is $H = V\Delta A$, and thence the electric force $\dot{\Sigma} = V\Delta H$.

If the vibration on the oscillator be simply periodic it is easy to see that the form of E is

$$E = E_1 \cos \frac{2\pi t}{\tau} + E_2 \sin \frac{2\pi t}{\tau},$$

where E_1 and E_2 are two vectors, so that E is the vector of an ellipse.

In determining the period of vibration of an oscillator the difficulty arises that the energy is being dissipated by radiation, and that some impressed forces must

be exerted on the oscillator to keep the vibration simply periodic, and if the impressed force be of a proper period any period of vibration is possible. To solve the problem a system of equal incoming waves is superposed on the outgoing ones, and then the simply periodic vibration is possible without any impressed force, and this condition then gives the free period of vibration.

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7. *Magnetic Action on Light.* *By* J. LARMOR, *F.R.S.*

This Paper was ordered by the General Committee to be printed *in extenso.* See Reports, p. 335.

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8. *On a Special Class of Generating Functions in the Theory of Numbers.* *By* Major P. A. MACMAHON, *R.A., F.R.S.*

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9. *On Agreeable Numbers.* *By* Lieut.-Col. ALLAN CUNNINGHAM, *R.E., Fellow of King's College, London.*

A number, N, of which the m digits on the right hand are the same as the m digits on the right hand of its nth power (N^n), when both are expressed in the scale whose radix is r, is styled an AGREEABLE NUMBER *of the* m*th order and* n*th degree in the* r*-ary scale.* When the agreement of N, a number of m digits, with its nth power, extends throughout its m digits, the number N is styled a Complete Agreeable Number. The analytical condition is

$$N^n - N \text{ must be divisible by } r^m.$$

The properties of these numbers are investigated in a quite general manner applicable to any scale of radix r; and *simple* rules for their computation given. These rules are completely reduced for the *denary* scale to their simplest form, and the auxiliary quantities are tabulated. Computations of complete agreeable numbers are given in detail for the denary scale. Tables are given of all agreeable numbers to the *fifth* order, and in some cases to the *tenth* order.

Example.—The numbers, N, of ten digits (shown in table below), and also the numbers of fewer digits obtainable therefrom by erasing one or more of the extreme left-hand digits of N, are *complete agreeables* in all the degrees n stated in column n; and are, moreover, the *only complete agreeables* (of ten digits, or less, ending in 1, 2, 4, 5, 6, 8) in all those degrees, except when n has the critical forms named in column n', in which case there are a *number* of complete agreeables (increasing rapidly with the value of n' and with the number of digits of N).

N	n	n'	—
0,000,000,001	Any *even* number	$5\Omega + 1$	*Notation*
8,212,890,625	Any number	Ω	Ω = an *odd* integer.
1,787,109,376	Any number	$5\mathrm{I} + 1$	
8,212,890,624	Any *odd* number	$10\Omega + 1$	
9,879,186,432	Any *odd* number of form $(4\nu+1)$	$20\Omega + 1$	I = any integer.
0,120,813,568	Any *odd* number of form $(4\nu+1)$	$20\Omega + 1$	

MONDAY, SEPTEMBER 18.

The following Reports and Papers were read:—

1. *Report of the Committee on Earth Tremors.*—See Reports, p. 287.

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2. *Report of the Committee on the Volcanic and Seismological Phenomena of Japan.*—See Reports, p. 214.

A discussion on the Teaching of Elementary Physics was introduced by the three following Papers:—

3. *Apparatus for Class-work in Elementary Practical Physics.* *By* Professor G. CAREY FOSTER, *F.R.S.*

The author described and exhibited samples of simple apparatus which he had devised for the purpose of practical instruction in physics. The object aimed at was to devise arrangements by which the chief quantitative laws of physics could be verified with fair accuracy, and which should at the same time be so inexpensive that they could be multiplied at a small cost, so that all the members of a class could make the same experiments at one time. In addition to the mere saving of expense, it was maintained that the simplification of apparatus, so long as it was efficient for its purpose, had the positive advantage of bringing students into more direct contact with the phenomena to be studied than was the case with more elaborate and complicated appliances.

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4. *On Physics Teaching in Schools.*[1] *By* W. B. CROFT, *M.A.*

It must be remembered that there are several classes of students:—

1. Those who aim at scientific or technical careers, but are compelled to make their education as brief as possible.

2. Those to whom science is the best education.

3. Those who may aspire to be mathematical physicists, and can afford to enjoy the benefit of wide and varied education.

4. The great majority receiving at our schools the usual general training in preparation for various professions. None of these should be without the benefits of science.

Of the first two classes I have not the experience to speak. The latter two appear to me to be well provided for under one scheme. Soon after the Duke of Devonshire's commission twenty years ago action was taken by the new governing bodies of public schools to make effective the recommendations of the British Association in 1867. At Winchester teachers and suitable apparatus were provided for the following scheme:—

If a boy were to pass up the school between the ages of twelve and nineteen, he would learn—

First year: Geometrical drawing, botany, physical geography.
Second year: Simple mechanics and graphics, hydrostatics, heat.
Third year: Chemistry.
Fourth year: Chemistry.
Fifth year: Geology.
Sixth year: Electricity.
Seventh year: Acoustics, geometrical and physical optics.
Two hours per week, with one or two hours out of school work.

Biology purposely has no place. It is better to be able to engage the interests of boys in it without reference to their age or position in the school. This is excellently done by a Natural History Society.

The general nature of teaching in the sixth and seventh years consists of experimental demonstrations of phenomena over as wide a range as possible. Boys who survive in a school to this stage are usually capable of appreciating scientific ideas through lectures, but in a public school they are seldom able to give time for practical work done by themselves. Those who may afterwards be thorough physicists had better be much occupied at this age with mathematics. So far as

[1] The full paper is published in the *Educational Times.*

possible they should avail themselves of the opportunities which most schools give for learning drawing, carpentering, and photography.

There is a significance in the order of subjects as arranged above. Experience shows that the subjects are suited to the various ages.

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5. *Notes on Science Teaching in Public Schools.* *By* A. E. HAWKINS, *B.Sc.*

The following 'items' represent convictions formed after twenty-two years' experience, the greater part of which (fifteen years) have been spent in the Bedford Modern School of about 600 boys.

I. The subject must be taught experimentally. The author has known splendid examinational results obtained without a single experiment having been performed by either teacher or taught.

In the hands of an experienced and vivacious teacher it is astonishing what mere drawings on the blackboard can accomplish for examinational purposes, disastrous, however, to real science.

Experiments involve the expenditure of much time; very frequently one is enough for a lesson—*e.g.*, determination of a specific heat or the resistance of a wire. If it is asked how an examination can be passed when time is so short, the answer is 'Teach, and let the examination take care of itself.' Where real teaching exists a pupil, worthy of the name, will soon find ways and means of getting up collateral matter.

But an experiment is not everything. It must be led up to. It must be preceded by discussion, and questions and answers should follow.

The conversational method is very difficult, especially with classes of thirty or more. Only one or two points can be made in a three-quarters of an hour lesson, and the matter must be clearly summed up at the end. The other quarter of an hour should be spent in writing an answer to a good comprehensive question. The answers should be marked and returned at the beginning of the next lesson.

II. But this is only half the work; experiments must now be done by the boys themselves. But practical work means plenty of apparatus, which in the majority of cases is not expensive. For a class of thirty boys ten sets at least will be required, which will allow three boys to work together. It is, however, much better if they can be arranged in pairs.

The boys, having done their experiments, should take their rough results home, and bring to the next lesson a clean copy and a detailed account of the method, with a drawing where desirable.

III. The work required of a pupil must frequently be, as far as he is concerned, original. A class, long accustomed to mere reproduction of the teacher's words and ideas, will feel unwonted life and delight if requested to devise some improvement upon a method just used, or to say what they would expect to happen if some modification were made. This is one of the surest ways of engendering an intelligent interest in the subject taught.

IV. What science should be taught? Heat and magnetism are the two best where expense is a primary consideration, and it is desired to get to work at once. Electricity should come afterwards, as so much of the subject, even in the simplest experiments, requires explanations which must be based on theory.

V. The teacher must have time allowed him to prepare the apparatus. Like other masters he has to prepare his lectures and also to correct exercises, but besides the preparation he has frequently to manufacture apparatus. This requires an expenditure of time which is, unfortunately, sometimes unrecognised.

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6. *Report of the Committee on the Application of Photography to Meteorological Phenomena.*—See Reports, p. 140.

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7. *Report of the Ben Nevis Committee.*—See Reports, p. 214.

TUESDAY, SEPTEMBER 19.

The following Reports and Papers were read:—

1. *Report of the Electrical Standards Committee.*—See Reports, p. 127.

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2. *On Standards of Low Electrical Resistance.* *By* Professor J. VIRIAMU JONES.

[This paper forms Appendix III. of the Report of the Electrical Standards Committee.—See Reports, p. 137.]

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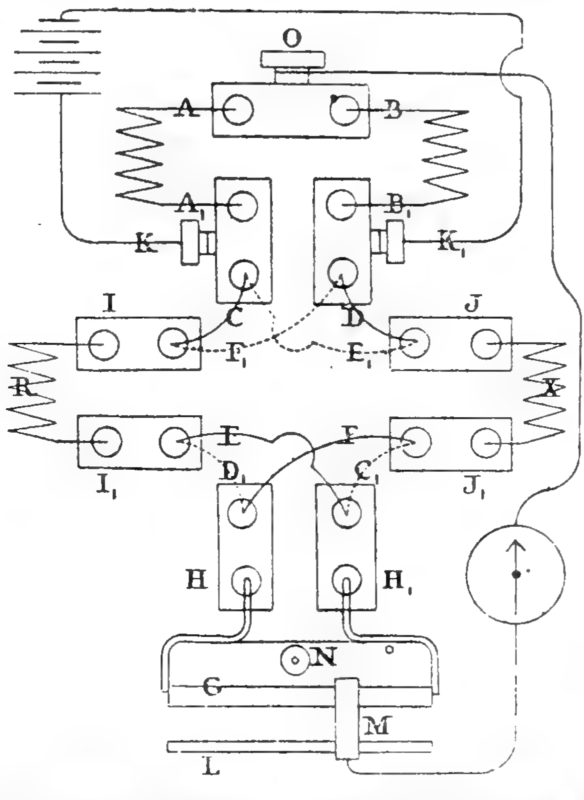
3. *An Apparatus for Comparing nearly Equal Resistances.* *By* F. H. NALDER.

The instrument shown fulfils the purpose of commutating the resistances to be compared with respect to the ratio resistance coils and a series of bridge wires, to be used according to the value of the coils under comparison. It consists of copper bars mounted on an ebonite base, and furnished with mercury cups for making the necessary contacts.



At A A_1 and B B_1 are the cups for the ratio coils, which are wound upon one bobbin and usually of the value of 1^w, 10^w, 100^w, and $1{,}000^w$ on each side. At I I_1 and J J_1 are placed the resistances whose difference is to be measured, and at G is the slide wire mounted on a detachable frame, with the key M, which runs on the divided rod L for making contact.

C D E F show the commutator connections in the first position, and after commutation in the position $C_1D_1E_1F_1$ as indicated by the dotted lines.

In order to commutate the coils R and X, the ebonite plate upon which the connections C D E F are mounted is drawn up against the spring which presses the contacts into their respective cups, until the guide pin is lifted out of its recess. The plate can then be turned through 180° till the contacts are in the position shown by the dotted lines marked $C_1D_1E_1F_1$; the galvanometer is then brought to zero by moving the contact key M into another position on its wire.

The battery connections are shown at $K K_1$ and those of the galvanometer at M O.

In order to obtain a wide range of measurement, instead of using a long wire a number of short bridge wires are provided, usually about ten, though if necessary this number need not be considered the limit.

The plate upon which each wire is mounted is detachable, as already stated, and in addition to the milled head N two steady pins are fixed in the base of the commutator so that it or any of the series can always be replaced accurately in position with respect to the scale and key.

A considerable variation of resistance of the short bridge wires shown will not vitiate the accuracy of the measurement.

This apparatus has been in use for the last five years substantially as now shown.

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4. *Note on a Galvanometer suited to Physiological Use.* *By* Dr. OLIVER LODGE, *F.R.S., and* F. H. NALDER.

Physiologists require galvanometers for exhibiting very small transient currents, but they seem often to use highly damped galvanometers for the purpose.

The first-named author, after some experiences with Professor Gotch, concluded that a more suitable galvanometer could be designed, and accordingly sent a sketch to Messrs. Nalder Brothers, who have carried it out.

The main points are:—

1. Extreme lightness and small moment of inertia of needle.
2. Great intensity of magnetisation.
3. Wire brought very close to the needle, so as to give a strong field without excessive resistance, and to have many small coils in preference to few big ones.
4. To avoid damping and to secure a long period by delicate suspension film rather than by heavy needle.
5. To use either a bee sting or some other sharp point in field of microscope for reading, wherever a spot of light is inconvenient.

The last condition has not been attended to yet, and perhaps biologists would not care for it. The second-named author finds the sensitiveness of a galvanometer as above designed with 8 coils two or three times as sensitive as usual.

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5. *On a Simple Interference Arrangement.* *By* Lord RAYLEIGH, *Sec.R.S.*

If a point, or line, of light be regarded through a telescope, the aperture of which is limited to two narrow parallel slits, interference bands are seen, of which the theory is given in treatises on Optics. The width of the bands is inversely proportional to the distance between the centres of the slits, and the width of the field, upon which the bands are seen, is inversely proportional to the width of the individual slits. If the latter element be given, it will usually be advantageous to approximate the slits until only a small number of bands are included. In this way not only are the bands rendered larger, but illumination may be gained by the then admissible widening of the original source.

Supposing, then, the proportions of the double slit to be given, we may inquire as to the effect of an alteration in scale. A diminution in ratio m will have the effect of magnifying m times the field and the bands (fixed in number) visible upon it. Since the total aperture is diminished m times, it might appear that the illumination would be diminished m^2 times, but the admissible widening of the

original source m times reduces the loss, so that it stands at m times, instead of m^2 times.

It remains, and this is more particularly the object of the present note, to point out the effect of the telescope upon the angular magnitude and illumination of the bands. If the magnifying power of the telescope exceed the ratio of aperture of object glass and pupil, its introduction is prejudicial. And even if the above limit be not exceeded, the use of the telescope is without advantage. The relation between the greatest brightness and the apparent magnitude of the bands is the same whether a telescope be used or not, the loss by reflections and absorptions being neglected. *The function of the telescope is merely to magnify the linear dimensions of the slit system.*

This magnification is sometimes important, especially when it is desirable to operate separately upon the interfering pencils. But when the object is merely to see the bands, the telescope may be abolished without loss. The only difficulty is to construct the very diminutive slit system then required. In the arrangement now exhibited, the slits are very fine lines formed by ruling with a knife upon a silver film supported upon glass. This double slit is mounted at one end of a tube, and at the other is placed a parallel slit. It then suffices to look through the tube at a candle or gas flame in order to see interference bands in a high degree of perfection.

It is suggested that this simple apparatus could be turned out very cheaply, and that its introduction into the market would tend to popularise acquaintance with interference phenomena.

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6. *On the Construction of Specula for Reflecting Telescopes upon New Principles.*[1] *By* Dr. A. SHAFARIK.

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7. *Supplementary Note on the Ether.* *By* Dr. OLIVER LODGE, *F.R.S.*

After my paper on Friday asserting no mechanical stress connection between ether and matter, Mr. Cowper Ranyard asked me, 'How, then, does dust polarise light?' Or more generally the question might be asked, 'How can ordinary matter affect light in any way?'

The note is suggested by that question, and the point of it is that since the dust is not electrified it cannot (*ex hypothesi*) be acted on by oscillating ether, but only by electric oscillations. (The action of dust on the electromagnetic theory has been explained by Lord Rayleigh.) Hence all elastic-solid, or mechanical theories of light appear to the author provisionally disproved.

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8. *On the Publication of Scientific Papers.* *By* A. B. BASSET, *M.A.*, *F.R.S.*

Two suggestions have been made with regard to the publication of scientific papers—first, that all papers of importance should be published in a central organ; secondly, that a digest containing an abstract of such papers should from time to time be published.

I do not think the first scheme could be carried out so as to serve any useful purpose; for, although it might suit the requirements of a few juvenile societies, it is unlikely that societies of position and standing, which have ample funds at their command for the publication of their proceedings and transactions, would consent to sink their individuality by giving up the publication of papers communicated to them. Moreover, as many societies derive a considerable portion of their income from the sale of their proceedings, it would be impossible for them to allow the concurrent publication of papers in the central organ, as this might seriously diminish their revenue.

[1] Published in full in *Industries*, 1893.

The importance of distributing copies of papers in quarters where they are likely to be read has been alluded to in 'Nature' by more than one correspondent. In order to do this effectively it is necessary that the author should receive a certain number of *gratuitous* copies. These are supplied by most scientific societies, and also by many of the American and foreign scientific journals. On the other hand, the 'Philosophical Magazine' refuses to present authors with any *gratuitous* copies, but makes them pay for any that they require. The question, therefore, arises as to whether the proposed 'central organ' is going to conduct its business on the principle embodied in the Latin maxim, *Do ut des, do ut facias, facio ut des, facio ut facias,* or whether it intends to follow the example of the 'Philosophical Magazine,' and try to get all it can without giving anything in return.

It appears to me most improbable that important and prosperous societies like the Cambridge Philosophical and the London Mathematical (to say nothing of the Royal) would lend a hand in promoting the scheme of a central organ; and in that event the scheme could not possibly be successful unless it were able to offer far greater advantages and attractions to authors than the societies do.

The only feasible scheme seems to be the publication of a digest of papers by the co-operation of the various scientific societies; and, if thought desirable, papers published in foreign countries might also be included. In order to prepare the way for such a digest, I should strongly recommend that in future all societies should follow the example of the Incorporated Society for Law Reporting, and require authors to append a headnote to their papers briefly setting forth the object of the investigation. Every three or four years the titles and headnotes of all papers relating to each separate branch of science should be copied out and arranged in proper order, and a series of digests of each separate branch of science should be published. Mathematicians would thus be enabled to purchase the mathematical digests, and chemists the chemical one. They would thereby be in a position to find out at a glance what papers have been published on their own special subjects during that period. These digests would do for science what the digests of law cases have done for the legal profession. Thirty years' experience has shown that this scheme would work well in practice; and as many country solicitors take in the 'Law Reports,' any member of the British Association who desires further information can easily obtain it by applying to one of the leading firms in Nottingham.

To develop an existing periodical which is a well-known and paying concern is often more successful than to start an entirely new one; and as many authors who contribute papers to societies send abstracts of them to 'Nature,' it might be worth while considering whether an arrangement could not be made with the proprietors of 'Nature' by which a supplemental number could be issued (say, once a quarter) containing a digest of the most important papers published in the United Kingdom during that period. The abstracts (with possibly a little pruning), and also the type used in setting them up, would be available, and the cost of compiling the supplemental number would have to be met by a small extra charge for it.

A committee of members of the British Association might be formed with advantage for discussing this matter, and drawing up a report embodying the recommendations at which they arrive. A copy of the report should then be sent as soon as practicable (*without waiting for the meeting next year*) to the presidents of the principal scientific societies, in order that it may be laid before their respective governing bodies. Each of the societies which are concerned with pure and applied mathematics and approve of united action could then appoint a delegate to discuss further proceedings with regard to their own particular subjects, and the same could be done by societies connected with other branches of science.

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9. *On a New Form of Air-pump.* *By* Professor J. J. THOMSON, *F.R.S.*

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10. *A Peculiar Motion assumed by Oil Bubbles in Ascending Tubes containing Caustic Solutions.* *By* F. T. TROUTON.

11. *On Electro-magnetic Trails of Images in Plane, Spherical, and Cylindrical Current Sheets.* By G. H. Bryan, *M.A.*

The problem of electro-magnetic induction in spherical and ellipsoidal current sheets has been dealt with by Professor Niven, Dr. Larmor, Professor Horace Lamb, and other writers, but, so far as the author is aware, no attempt has been made to apply the method of images to current sheets except in the well-known case of an infinite plane sheet, so fully treated by Maxwell and other writers. The author has worked out the images of a fixed magnetic pole of variable intensity in presence of a spherical current sheet, and has performed the corresponding investigation for the cylinder under the influence of a line distribution of magnetism of variable intensity parallel to the axis of the cylinder, the problem being in this case two dimensional. From the results thus obtained the images of a moving pole may be constructed in the same manner as for a plane sheet. In the particular case of a pole revolving outside a spherical shell about its centre, the images which determine the magnetic potential at any point *inside* the shell lie on an equiangular spiral.

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12. *On Thermal Relations between Air and Water.* By Hugh Robert Mill, *D.Sc., F.R.S.E.*

The conclusions stated in this paper were deduced mainly from the author's observations on the Clyde Sea Area. The physical character of the Clyde Sea Area depends mainly on the form of the hollows of which it is composed and the degree of isolation of each from oceanic influences. The North Channel between Scotland and Ireland was found always in a homothermic condition, *i.e.*, the temperature was the same from surface to bottom, an effect traced to the tidal mixing of the water. The Channel water was on the average of the whole year 1°·7 F., warmer than the air at the Mull of Cantyre. The air reached its maximum in the end of July, the water not until the middle of September. Up to that date the air was warmer, but from September to April the water was warmer. On the plateau or broad shallow stretching across the mouth of the Sea Area from Cantyre to Galloway the water was usually highly heterothermic, *i.e.*, the temperature varied greatly from surface to bottom. Only at the period of the annual minimum was the temperature uniform throughout. On the plateau the Channel water mixed with that of the great Arran basin, the deepest and most open of the natural divisions of the Clyde Sea Area. In the Arran basin the water was homothermic throughout at each spring minimum about the month of March, and as heat was being stored or lost the lower layers remained homothermic, becoming least so about the time of the autumn maximum. The surface layers heated up most rapidly, and cooled down most rapidly, but the average temperature of the whole mass of water was always lower than that of the Channel, except for about a month at the spring minimum. The maximum temperature of the mass also was retarded to the middle of October, up to which date the water as a whole was colder than the air, but after that date was warmer till the spring minimum. The condition of things in the more isolated barred off sea lochs, such as Loch Fyne and Loch Goil, showed still more strongly the effects of isolation from oceanic influence. The mass of the water in Loch Fyne, although nearly of the same temperature as the other divisions about the period of minimum, was much colder during the rest of the year than that of the Arran basin, which in turn was colder than the Channel. The date of maximum temperature was a few weeks later than that of the Arran basin, and at least three months later than that of the air. The difference between the behaviour of the surface and bottom water with regard to temperature became more and more marked with the degree of isolation from oceanic water. In Loch Fyne and Loch Goil the warmth of summer did not affect the bottom water for about six months, and the greatest cold of winter took about three months to make itself felt at the bottom.

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13. *On a New Artificial Horizon.* *By* W. P. Shadbolt.

14. *Investigations as to what would be the Laws which would Regulate the Transplacement of a Liquid by a Moving Body; and Reasons why Ether eludes our Senses.* *By* E. Major.

SECTION B.—CHEMICAL SCIENCE.

PRESIDENT OF THE SECTION—Professor J. EMERSON REYNOLDS, M.D., Sc.D., F.R.S.

THURSDAY, SEPTEMBER 14.

The PRESIDENT delivered the following Address:—

AT the Nottingham Meeting of the British Association in 1866, Dr. H. Bence Jones addressed the Section over which I have now the honour to preside on the place of Chemical Science in Medical Education. Without dwelling on this topic to-day, it is an agreeable duty to acknowledge the foresight of my predecessor as to the direction of medical progress. Twenty-seven years ago the methods of inquiry and instruction in medicine were essentially based on the formal lines of the last generation. Dr. Bence Jones saw that modern methods of research in chemistry—and in the experimental sciences generally—must profoundly influence medicine, and he urged the need of fuller training of medical students in those sciences.

The anticipated influence is now operative as a powerful factor in the general progress of medicine and medical education; but much remains to be desired in regard to the chemical portion of that education. In the later stages of it undue importance is still attached to the knowledge of substances rather than of principles; of products instead of the broad characters of the chemical changes in which they are formed. Without this higher class of instruction it is unreasonable to expect an intelligent perception of complex physiological and pathological processes which are chemical in character, or much real appreciation of modern pharmacological research. I have little doubt, however, that the need for this fuller chemical education will soon be so strongly felt that the necessary reform will come from within a profession which has given ample proof in recent years of its zeal in the cause of scientific progress.

In our own branch of science the work of the year has been substantial in character, if almost unmarked by discoveries of popular interest. We may probably place in the latter category the measure of success which the skill of Moissan has enabled him to attain in the artificial production of the diamond form of carbon, apparently in minute crystals similar to those recognised by Koenig, Mallard, Daubrée, and by Friedel in the supposed meteorite of Cañon de Diablo in Arizona. Members of the Section will probably have the opportunity of examining some of these artificial diamonds through the courtesy of M. Moissan, who has also, at my request, been so good as to arrange for us a demonstration of the properties of the element fluorine, which he succeeded in isolating in 1887.

Not less interesting or valuable are the studies of Dr. Perkin, on electro-magnetic rotation; of Lord Rayleigh, on the relative densities of gases; of Dewar, on chemical relations at extremely low temperatures; of Clowes, on exact measurements of flame-cap indications afforded by Miners' testing lamps; of Horace Brown and Morris, on the chemistry and physiology of foliage leaves, by which they have been led to the startling conclusion that cane-sugar is the first sugar produced during the assimilation of carbon, and that starch is formed at its expense as a more stable

reserve material for subsequent use of the plant; or of Cross, Bevan, and Beadle, on the interaction of alkali-cellulose and carbon bisulphide, in the course of which they have proved that a cellulose residue can act like an alcohol radical in the formation of thiocarbonates, and thus have added another to the authors' valuable contributions to our knowledge of members of the complex group of celluloses.

But it is now an idle task for a President of this Section to attempt a slight sketch of the works of chemical philosophers even during the short space of twelve months; they are too numerous and generally too important to be lightly treated, hence we can but apply to them a paraphrase of the ancient formula—Are they not written in the books of the chronicles we term 'Jahresberichte,' 'Annales,' or 'Transactions and Abstracts,' according to our nationality?

I would, however, in this connection ask your consideration for a question relating to the utilisation of the vast stores of facts laid up—some might even say buried—in the records to which reference has just been made. The need exists, and almost daily becomes greater, for facile reference to this accumulated wealth, and of such a kind that an investigator, commencing a line of inquiry with whose previous history he is not familiar, can be certain to learn *all* the facts known on the subject up to a particular date, instead of having only the partial record to be found in even the best edited of the dictionaries now available. The best and most obvious method of attaining this end is the publication of a subject-matter index of an ideally complete character. I am glad to know that the Chemical Society of London will probably provide us in the years to come with a compilation which will doubtless aim at a high standard of value as a work of reference to memoirs, and in some degree to their contents, so far as the existing indexes of the volumes of the Society's Journal supply the information. Whether this subject-matter index is published or not, the time has certainly arrived for adopting the immediately useful course of publishing monographs, analogous to those now usual in Natural Science, which shall contain all the information gained up to a particular date in the branch of chemistry with which the author is specially familiar by reason of his own work in the subject. Such monographs should include much more than any mere compilation, and would form the best material from which a complete subject-matter index might ultimately be evolved.

My attention was forcibly drawn to the need of such special records by noting the comparatively numerous cases of re-discovery and imperfect identification of derivatives of thiourea. In my laboratory, where this substance was isolated, we naturally follow with interest all work connected with it, and therefore readily detect lapses of the kind just mentioned. But when it is remembered that the distinct derivatives of thiourea now known number considerably over six hundred substances, and that their descriptions are scattered through numerous British and foreign journals, considerable excuse can be found for workers overlooking former results. The difficulty which exists in this one small department of the science I hope shortly to remove, and trust that others may be induced to provide similar works of reference to the particular branches of chemistry with which they are personally most familiar.

When we consider the drift of investigation in recent years, it is easy to recognise a distinct reaction from extreme specialisation in the prominence now given to general physico-chemical problems, and to those broad questions concerning the relations of the elements which I would venture to group under the head of 'Comparative Chemistry.' Together these lines of inquiry afford promise of definite information about the real nature of the seventy or more entities we term 'elements,' and about the mechanism of that mysterious yet definite change in matter which we call 'chemical action.' Now and again one or other class of investigation enables us to get some glimpse beyond the known which stimulates the imaginative faculty.

For example, a curious side-light seems to be thrown on the nature of the elements by the chemico-physical discussion of the connection existing between the constitution of certain organic compounds and the colours they exhibit. Without attempting to intervene in the interesting controversy in which Armstrong and Hartley are engaged as to the nature of the connection, we may take it as an

established fact that a relation exists between the power which a dissolved chemical compound possesses of producing the colour impression within our comparatively small visual range, and the particular mode of grouping of its constituent radicals in its molecule. Further, the reality of this connection will be most freely admitted in the class of aromatic compounds; that is, in derivatives of benzene, whose constituents are so closely linked together as to exhibit quasi-elemental persistence. If, then, the possession of what we call colour by a compound be connected with its constitution, may we not infer that 'elements' which exhibit distinct colour, such as gold and copper, in thin layers and in their soluble compounds, are at least complexes analogous to definitely decomposable substances? This inference, while legitimate as it stands, would obviously acquire strength if we could show that anything like isomerism exists among the elements; for identity of atomic weight of any two chemically distinct elements must, by all analogy with compounds, imply dissimilarity in constitution, and, therefore, definite structure, independently of any argument derived from colour. Now, nickel and cobalt are perfectly distinct elements, as we all know, but, so far as existing evidence goes, the observed differences in their atomic weights (nickel 58·6, cobalt 58·7) are so small as to be within the range of the experimental errors to which the determinations were liable. Here, then, we seem to have the required example of something like isomerism among elements, and consequently some evidence that these substances are complexes of different orders; but in the cases of cobalt and nickel we also know that in transparent solutions of their salts, if not in thin layers of the metals themselves, they exhibit strong and distinct colours—compare the beautiful rosy tint of cobalt sulphate with the brilliant green of the corresponding salt of nickel. Therefore, in exhibiting characteristically different colours, these substances afford us some further evidence of structural differences between the matter of which they consist, and support the conclusion to which their apparent identity in atomic weight would lead us. By means of such side-lights we may gradually acquire some idea of the nature of the elements, even if we are unable to get any clue to their origin other than such as may be found in Crookes' interesting speculations.

Again, while our knowledge of the genesis of the chemical elements is as small as astronomers possess of the origin of the heavenly bodies, much suggestive work has recently been accomplished in the attempt to apply the principle of gravitation, which simply explains the relative motions of the planets, to account for the interactions of the molecules of the elements. The first step in this direction was suggested by Mendeleef in his Royal Institution lecture (May 31, 1889), wherein he proposed to apply Newton's third law of motion to chemical molecules, regarded as systems of atoms analogous to double stars. The Rev. Dr. Haughton has followed up this idea with his well-known mathematical skill, and, in a series of papers just published, has shown that the three Newtonian laws are applicable to explain the interactions of chemical molecules, 'with this difference, that whereas the specific coefficient of gravity is the same for all bodies, independent of the particular kind of matter of which they are composed, the atoms have specific coefficients of attraction which vary with the nature of the atoms concerned.' The laws of gravitation, with this proviso, were found to apply to all the definite cases examined, and it was shown that a chemical change of combination is equivalent to a planetary catastrophe. So far the fundamental hypothesis of 'Newtonian Chemistry' has led to conclusions which are not at variance with the facts of the science, while it gives promise of help in obtaining a solution of the great problem of the nature of chemical action.

Passing from considerations of the kind to which I have just referred, permit me to occupy the rest of the time at my disposal with a short account of a line of study in what I have already termed 'comparative chemistry,' which is not only of inherent interest, but seems to give us the means of filling in some details of a hitherto rather neglected chapter in the early chemical history of this earth.

The most remarkable outcome of 'comparative chemistry' is the periodic law of the elements, which asserts that the properties of the elements are connected in the form of a periodic function with the masses of their atoms. Concurrently with the recognition of this principle, other investigations have been in progress, aiming

at more exact definitions of the characters of the relations of the elements, and ultimately of their respective offices in nature. Among inquiries of this kind the comparative study of the elements carbon and silicon appears to me to possess the highest interest. Carbon, whether combined with hydrogen, oxygen, or nitrogen, or with all three, is the great element of organic nature, while silicon, in union with oxygen and various metals, not only forms about one-third of the solid crust of the earth, but is unquestionably the most important element of inorganic nature. The chief functions of carbon are those which are performed at comparatively low temperatures; hence carbon is essentially the element of the present epoch. On the other hand, the activities of silicon are most marked at very high temperatures; hence it is the element whose chief work in nature was performed in the distant past, when the temperature of this earth was far beyond that at which the carbon compounds of organic life could exist. Yet between these dominant elements of widely different epochs remarkably close analogies are traceable, and the characteristic differences observed in their relations with other elements are just those which enable each to play its part effectively under the conditions which promote its greatest activity.

The chemical analogies of the two tetrad elements carbon and silicon are most easily recognised in compounds which either do not contain oxygen, or which are oxygen compounds of a very simple order, and the following table will recall a few of the most important of these, as well as some which have resulted from the fine researches of Friedel, Crafts, and Ladenburg:—

Some Silicon Analogues of Carbon Compounds.

SiH_4	Hydrides	CH_4
$SiCl_4$	Chlorides	CCl_4
Si_2Cl_6	Chlorides	C_2Cl_6
SiO_2	Oxides	CO_2
H_2SiO_3	Meta Acids	H_2CO_3
$HSiHO_2$	Formic Acids	$HCHO_2$
$(SiHO)_2O$	Formic Anhydrides	$(CHO)_2O$?
$H_2Si_2O_4$	Oxalic Acids	$H_2C_2O_4$
$HSi(CH_3)O_2$	Acetic Acids	$HC(CH_3)O_2$
$HSi(C_6H_5)O_2$	Benzoic Acids	$HC(C_6H_5)O_2$
$SiC_8H_{19}H$	Nonyl Hydrides	$C_9H_{19}H$
$SiC_8H_{19}OH$	Nonyl Alcohols	$C_9H_{19}OH$

But these silicon analogues of carbon compounds are, generally, very different from the latter in reactive power, especially in presence of oxygen and water. For example, hydride of silicon, even when pure, is very easily decomposed, and, if slightly warmed, is spontaneously inflammable in air; whereas the analogous marsh gas does not take fire in air below a red heat. Again, the chlorides of silicon are rapidly attacked by water affording silicon hydroxides and hydrochloric acid; but the analogous carbon chlorides are little affected by water even at comparatively high temperatures. Similarly, silicon-chloroform and water quickly produce silico-formic acid and anhydride along with hydrochloric acid, while ordinary chloroform can be kept in contact with water for a considerable time without material change.

Until recently no well-defined compounds of silicon were known including nitrogen; but we are now acquainted with a number of significant substances of this class.

Chemists have long been familiar with the fact that a violent reaction takes place when silicon chloride and ammonia are allowed to interact. Persoz, in 1830, assumed that the resulting white powder was an addition compound, and assigned to it the formula $SiCl_4$, 6 NH_3, while Besson, as lately as 1892, gave $SiCl_4$, 5 NH_3. These formulæ only express the proportions in which ammonia reacts with the chloride under different conditions, and give us no information as to the real nature of the product; hence they are almost useless. Other chemists have, however, carefully examined the product of this reaction, but owing to peculiar difficulties

in the way have not obtained results of a very conclusive kind. It is known that the product when strongly heated in a current of ammonia gas affords ammonium chloride, which volatilises, and a residue, to which Schutzenberger and Colson have assigned the formula Si_2N_3H. This body they regard as a definite hydride of Si_2N_3, which latter they produced by acting on silicon at a white heat with pure nitrogen. Gattermann suggests that a nearer approach to the silicon analogue of cyanogen, Si_2N_2, should be obtained from the product of the action of ammonia on silicon-chloroform; but it does not appear that this suggestion has yet borne fruit. It was scarcely probable that the above-mentioned rather indefinite compounds of silicon with nitrogen were the only ones of the class obtainable, since bodies including carbon combined with nitrogen are not only numerous but are among the most important carbon compounds known. Further investigation was therefore necessary in the interests of comparative chemistry, and for special reasons which will appear later on; but it was evident that a new point of attack must be found.

A preliminary experimental survey proved the possibility of forming numerous compounds of silicon containing nitrogen, and enabled me to select those which seemed most likely to afford definite information. For much of this kind of work silicon chloride was rather too energetic, hence I had a considerable quantity of the more manageable silicon tetrabromide prepared by Serullas' method, viz., by passing the vapour of crude bromine (containing a little chlorine) over a strongly heated mixture of silica and charcoal. In purifying this product I obtained incidentally the chloro-bromide of silicon, $SiClBr_3$, which was required in order to complete the series of possible chlorobromides of silicon.[1]

Silicon bromide was found to produce addition compounds very readily with many feebly basic substances containing nitrogen. But one group of bromides of this class has yet been investigated in detail, namely, the products afforded by thioureas. The typical member of this group is the perfectly definite but uncrystalline substance

$$SiBr_2\begin{cases}(CSN_2H_4)_4Br\\(CSN_2H_4)_4Br\end{cases}$$

Substituted thioureas afford similar bodies, the most interesting of which is the allyl compound. This is a singularly viscid liquid, which requires several days at ordinary temperatures to regain its level, when a tube containing it is inverted. But these are essentially addition compounds, and are therefore comparatively unimportant.

In most cases, however, the silicon haloids enter into very definite reaction with nitrogen compounds, especially when the latter are distinctly basic, such as aniline or any of its homologues. One of the principal products of this class of change is the beautiful typical substance on the table, which is the first well-defined crystalline compound obtained in which silicon is exclusively combined with nitrogen. Its composition is $Si(NHC_6H_5)_4$.[2] Analogous compounds have been formed with the toluidines, naphthylamines, &c., and have been examined in considerable detail, but it suffices to mention them and proceed to point out the nature of the changes we can effect by the action of heat on the comparatively simple anilide.

When silicon anilide is heated carefully *in vacuo* it loses one molecule of aniline very easily and leaves triphenyl-guanidine, probably the *a* modification; if the action of heat be continued, but at ordinary pressure and in a current of dry hydrogen, another molecule of aniline can be expelled, and, just before the last trace of the latter is removed, the previously liquid substance solidifies and affords a silicon analogue of the insoluble modification of carbodiphenyldiimide, which may then be heated moderately without undergoing further material change. A comparison of the formulæ will make the relations of the products clear:—

Silicotetraphenylamide—$Si(NHPh)_4$
Silicotriphenylguanidine—$Si : NPh.(NHPh)_2$
Silicodiphenyldiimide—$Si : (NPh)_2$.

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[1] Three years later Besson formed the same compound and described it as new.

[2] Harden has obtained an uncrystalline intermediate compound, $SiCl_2(NHC_6H_5)_2$.

Moreover, the diimide has been heated to full redness in a gas combustion furnace while dry hydrogen was still passed over it; even under these conditions little charring occurred, but some nitrogen and a phenyl radical were eliminated, and the purified residue was found to approximate in composition to SiNPh, which would represent the body as phenylsilicocyanide or a polymer of it. Even careful heating of the diimide in ammonia gas has not enabled me to remove all the phenyl from the compound, but rather to retain nitrogen, as the best residue obtained from such treatment consisted of Si_2N_3Ph, or the phenylic derivative of one of the substances produced by Schutzenberger and Colson from the ammonia reaction. It may be that both these substances are compounds of silicocyanogen with an imide group of the kind indicated below—

$$\begin{matrix} \mathrm{SiN}\diagdown & \\ & \mathrm{NH} \\ \mathrm{SiN}\diagup & \end{matrix} \quad : \quad \begin{matrix} \mathrm{SiN}\diagdown & \\ & \mathrm{NPh} \\ \mathrm{SiN}\diagup & \end{matrix}$$

Further investigation must decide whether this is a real relationship; if it be, we should be able to remove the imidic group and obtain silicocyanogen in the free state. One other point only need be noticed, namely, that when the above silicon compounds are heated in oxygen they are slowly converted into SiO_2; but the last traces of nitrogen are removed with great difficulty, unless water-vapour is present, when ammonia and silica are quickly formed.

Much remains to be done in this department of comparative chemistry, but we may fairly claim to have established the fact that silicon, like carbon, can be made to form perfectly well-defined compounds in which it is exclusively united with the triad nitrogen of amidic and imidic groups.

Now, having proved the capacity of silicon for the formation of compounds of this order with a triad element, Nature very distinctively lets us understand that nitrogen is not the particular element which is best adapted to play the triad rôle towards silicon in its high-temperature changes, which are ultimately dominated by oxygen. We are not acquainted with any natural compounds which include silicon and nitrogen; but large numbers of the most important minerals contain the pseudo-triad element aluminium combined with silicon, and few include any other triad. Phosphorus follows silicon in the periodic system of the elements as nitrogen does carbon, but silicates containing more than traces of phosphorus are rare; on the other hand, several silicates are known containing boron, the lower homologue of aluminium; for example, axinite, datholite, and tourmaline.

Moreover, it is well known that silicon dissolves freely in molten aluminium, though much of the former separates on cooling. Winkler has analysed the gangue of aluminium saturated with silicon, and found that its composition is approximately represented by the formula SiAl, or, perhaps, Si_2Al_2, if we are to regard this as analogous to C_2N_2 or cyanogen. Here aluminium at least resembles nitrogen in directly forming a compound with silicon at moderately high temperature. It would appear, then, that while silicon can combine with both the triads nitrogen and aluminium, the marked positive characters of the latter, and its extremely low volatility, suit it best for the production of permanent silicon compounds similar to those which nitrogen can afford.

With these facts in mind we may carry our thoughts back to that period in the earth's history when our planet was at a higher temperature than the dissociation point of oxygen compounds. Under such conditions the least volatile elements were probably liquids, while silicides and carbides of various metals were formed in the fluid globe. We can imagine that the attraction of aluminium for the large excess of silicon would assert itself, and that, as the temperature fell below the point at which oxidation became possible, these silicides and carbides underwent some degree of oxidation, the carbides suffering most owing to the volatility of the oxides of carbon, while the fixity of the products of oxidation of silicides rendered the latter process a more gradual one. The oxidation of silicides of metals which had little attraction for silicon would lead to the formation of simple metallic silicates and to the separation of the large quantities of free silica we meet with in the solid crust of the earth, whereas oxidation of silicides of aluminium would not

break up the union of the two elements, but rather cause the ultimate formation of the alumino-silicates which are so abundant in most of our rocks.

Viewed in the light of the facts already cited and the inferences we have drawn from them as to the nitrogen-like relationship of aluminium to silicon, I am disposed to regard the natural alumino-silicates as products of final oxidation of sometime active silico-aluminium analogues of carbo-nitrogen compounds, rather than ordinary double salts. It is generally taken for granted that they are double salts, but recent work on the chromoxalates by E. A. Werner has shown that this view is not necessarily true of all such substances.

Without going into undue detail we can even form some conception of the general course of change from simple aluminium silicide to an alumino-silicate, if we allow the analogies already traced to lead us further.

We recognise the existence of silico-formyl in Friedel and Ladenburg's silico-formic anhydride; hence silico-triformamide is a compound whose probable formation we can admit, and, on the basis of our aluminium-nitrogen analogy, an aluminium representative also. Thus—

$$\begin{array}{ccccccc}
\mathrm{N}\begin{array}{l}\diagup \mathrm{COH}\\ -\mathrm{COH}\\ \diagdown \mathrm{COH}\end{array} & : & \mathrm{N}\begin{array}{l}\diagup \mathrm{SiOH}\\ -\mathrm{SiOH}\\ \diagdown \mathrm{SiOH}\end{array} & : & \mathrm{Al}\begin{array}{l}\diagup \mathrm{SiOH}\\ -\mathrm{SiOH}\\ \diagdown \mathrm{SiOH}\end{array} & : & \mathrm{Al}\begin{array}{l}\diagup \mathrm{SiO_2R'}\\ -\mathrm{SiO_2R'}\\ \diagdown \mathrm{SiO_2R'}\end{array}
\end{array}$$

Triformamide. Silico-triformamide. Silico-alumino-triformamide. Salt of an alumino-silicic acid.

Now, oxidation of triformamide would lead to complete resolution into nitrogen gas, carbondioxide gas and water rendering it an extremely unstable body; under similar conditions silico-triformamide would probably afford nitrogen gas and silicic acid (or silicon dioxide and water); while the third compound, instead of breaking up, would (owing to the fixity of aluminium as compared with nitrogen) be likely at first to afford a salt of an alumino-silicic acid, in presence of much basic material.

The frequent recurrence of the ratios Si_3Al, Si_3Al_2, &c., in the formulæ of natural alumino-silicates, suggests that some at least of these minerals are derived from oxidation products of the above triformic type. Without stopping to trace all the possible stages in the oxidation of the primary compound $Al(SiO_2R)_3$, or variations in basicity of the products, I may cite the four following examples out of many others which might be given of resulting representative mineral groups:—

$$\begin{array}{ccccccc}
\mathrm{Al}\begin{array}{l}\diagup \mathrm{SiO_3R'}\\ -\mathrm{SiO_3R'}\\ \diagdown \mathrm{SiO_3R'}\end{array} & : & \mathrm{Al}\begin{array}{l}\diagup \mathrm{SiO_4R'_3}\\ -\mathrm{SiO_4R'_3}\\ \diagdown \mathrm{SiO_4R'''}\end{array} & : & \mathrm{Al}\begin{array}{l}\diagup \mathrm{SiO_4R'_3}\\ -\mathrm{SiO_4R'''}\\ \diagdown \mathrm{SiO_4R'''}\end{array} & : & \mathrm{Al}\begin{array}{l}\diagup \mathrm{SiO_4R'''}\ {}^{1}\\ -\mathrm{SiO_4R'''}\\ \diagdown \mathrm{SiO_4R'''}\end{array}
\end{array}$$

Beryl type (hemi-). Garnet type. Muscovite type. Xenolite type.

Five years ago Professor F. W. Clarke, of the United States Geological Survey, published a most interesting paper on the structure of the natural silicates. In this he adopts the view that the mineral xenolite, $Si_3Al_4O_{12}$, is the primary from which all other alumino-silicates may be supposed to arise by various substitutions. Nature, however, seems to teach us that such minerals as xenolite, fibrolite, and the related group of 'clays' are rather to be regarded as end-products of a series of hydrolytic changes of less aluminous silicates than primary substances themselves; hence the sketch which I have ventured to give above of the probable genesis of alumino-silicates seems to provide a less arbitrary basis for Clarke's interesting work, without materially disturbing the general drift of his subsequent reasoning.

We may now consider for a moment in what direction evidence can be sought for the existence in nature of derivatives of the hypothetical intermediate products of oxidation between a primary silicide and its fully oxidised silicate.

[1] In these cases where $R''' = Al$ it is, of course, assumed that the latter is acting only as a basic radical.

In the absence of a working hypothesis of the kind which I have already suggested, it is not probable that direct evidence would yet be obtainable—this must be work for the future—but when we consider that the existence of compounds of the order in question would manifest themselves in ordinary mineral analyses by the analytical products exceeding the original weight of material, we seem to find some evidence on the point in recorded cases of the kind. A deficiency of a single atom of oxygen in compounds having the high molecular weights of those in question would be indicated by very small excesses (from 2 to 3 per cent.) whose real meaning might be easily overlooked. Now, such results are not at all unusual in analyses of mineral alumino-silicates. For instance, *Amphiboles* containing a mere trace of iron have afforded 102·75 parts from 100, and almost all analyses of *Microsommite* are high, giving as much as 103 parts. In less degree *Vesuvianite* and members of the *Andalusite* group may be noted. All these cases may be capable of some other explanations, but I cite them to show that such excesses are commonly met with in published analyses. On the other hand, it is scarcely to be doubted that a good analyst, who obtained a really significant excess, would throw such a result aside as erroneous and never publish it. I therefore plead for much greater care in analyses of the kind in question and closer scrutiny of results in the light of the suggestions I have ventured to offer. It is probable that silicates containing only partially oxidised aluminium are rare; nevertheless the search for them would introduce a new element of interest into mineralogical inquiries.

If the general considerations I have now endeavoured to lay before you are allowed their full weight, some of the alumino-silicates of our primary rocks reveal to us more than we hitherto supposed. Regarded from this newer standpoint, they are teleoxidised representatives of substances which foreshadowed in terms of silicon, aluminium, and oxygen the compounds of carbon, nitrogen, and hydrogen required at a later stage of the earth's history for living organisms. Thus, while the sedimentary strata contain remains which come down to us from the very dawn of life on this globe, the rocks from whose partial disintegration the preserving strata resulted contain mineral records which carry us still further back, even to Nature's earliest efforts in building up compounds similar to those suited for the purposes of organic development.

The following Papers and Reports were read:—

1. *On Tools and Ornaments of Copper and Other Metals from Egypt and Palestine. By* Dr. J. H. Gladstone, *F.R.S.*

The author gave an account of analyses of various specimens of metallic tools and ornaments found by Dr. Flinders Petrie in Egypt and Mr. Bliss in Palestine. The oldest copper tools were from Meydum, and date back probably to the fourth Egyptian dynasty, about 3500 B.C. Other copper tools were obtained at Kahun, and date 2500 B.C. These contain small quantities of arsenic, antimony, &c.; but among the specimens from Meydum was a rod of bronze containing about 9 per cent. of tin. Bronze needles were also found at Kahun, and of course bronze was abundant in later periods. That tin was known in the metallic condition was evidenced by a finger-ring made of tin belonging to the eighteenth dynasty, about 1400 B.C. Lead was often mixed with the bronze for the casting of statuettes.

The mound of Tel-el-Hesy, which is believed to be the Lachish of the Scriptures, consists of the ruins of several successive Amorite towns, above which are the ruins of the Israelitish town. A copper tool from the lowest stratum, and which could not be of later date than 1500 B.C., was made of a very red, hard, brittle metal, of a specific gravity of only 6·6, and consisted of cuprous oxide to the extent of about 25 per cent. This oxide, no doubt, gave the desired hardness to the copper. In the strata dating from 1400 B.C. to 800 B.C. occurred many arrow-heads and other objects made of bronze. In the upper Israelitish portion the bronze implements were gradually replaced by iron. At Lachish there were also found a wire of almost pure lead, and what seemed to be a bracelet of silver. The latter was

coated with chloride of silver, doubtless from the chlorides in the soil, and contained 6·5 per cent. of copper and 1·44 per cent. of gold.

At Illahun, in Egypt, some beads or buttons were found which proved to be of metallic antimony badly reduced from the sulphide. They date back to about 800 B.C.

2. *Report on International Standards for the Analysis of Iron and Steel.*

See Reports, p. 437.

3. *On Native Iron Manufacture in Bengal. By* H. Harris *and* T. Turner.

4. *On Nitride of Iron. By* G. J. Fowler, *M.Sc.*

This research was undertaken with the object of repeating and extending the work of Stahlschmidt ('Pogg. Ann.,' v. cxxv., 1865, p. 37) on the same subject, his results differing in many points from those of his predecessors.

The best way of preparing nitride of iron was found to be the following:—Iron is reduced from the hydrate by hydrogen, in a tube of such dimensions that it can be weighed, together with its contents, and thus the end of the reaction determined without exposing the iron to the air. When complete reduction has been effected, the iron is heated in a fairly rapid current of ammonia gas, until no further increase in weight is observed. The temperature should be kept a little above the melting-point of lead.

The product obtained when the reaction was complete was analysed. The nitrogen was determined by dissolving the substance in hydrochloric acid, evaporating with platinum chloride, and weighing the ammonium-platinum-chloride obtained.

The hydrogen given off on solution of the substance in sulphuric acid was measured.

The iron was determined by ignition and weighing as oxide, and by solution in sulphuric acid and titration with permanganate.

As will be seen from the results obtained, the nitride prepared as above has a composition corresponding to the formula Fe_2N. On solution in hydrochloric acid the following reaction takes place:—

$$Fe_2N + 5HCl = 2FeCl_2 + NH_4Cl + H.$$

	Found	Calculated for Fe_2N.
N	11·07	11·11
Fe	88·46 (mean of two titrations)	88·89
	88·43 (by ignition)	
H	23·1 c.c. from ·275 subst.	24·4 c.c

In another sample 10·94 N. was found. In a third case, in which the iron, after solution of the nitride in acid, was precipitated by ammonia and weighed as oxide, 89·44 per cent. of iron was obtained and 10·5 per cent. of nitrogen, showing again that the substance dissolves in acid according to the above equation, all the nitrogen being converted into ammonia.

No percentages of nitrogen above 11·1 could be obtained, while any percentage below that could be got according to the time during which the iron had been exposed to the current of ammonia.

These results are fully in agreement with those obtained by Stahlschmidt, and confirm his conclusion that only one nitride of iron exists, and that it has the above composition.

Nitride of iron is formed when iron amalgam is heated in ammonia, and also when ferrous chloride or bromide is heated in this gas. These methods, however, do not so readily give a product containing the full percentage of nitrogen, and free from the presence of a third element.

Nitride of iron is a grey powder, rather less blue in tone than iron reduced from

the hydrate. On rubbing it is more gritty than iron prepared as above. It is feebly magnetic.

Heated in hydrogen, ammonia is produced at about the same temperature as that at which the nitride is formed.

It readily burns in chlorine, ferric chloride and nitrogen being formed.

Heated in carbon monoxide, no evidence of the formation of cyanogen compounds could be obtained.

Steam at 100° slowly oxidises the nitride with evolution of ammonia.

Hydrogen sulphide begins to react with it at 200°, forming ammonium sulphide and sulphide of iron.

Heated in nitrogen to the boiling-point of sulphur, no change occurs. The temperature at which nitrogen is evolved by the action of heat alone must therefore be above this point.

An ethereal solution of iodine is without action upon the nitride.

From a slightly acidified solution of copper sulphate, nitride of iron deposits copper.

Heated with ethyl iodide to 200° in a sealed tube, olefines are formed, and iodides of iron and ammonium, the reaction evidently being

$$5C_2H_5I + Fe_2N = 2FeI_2 + NH_4I + 5C_2H_4 + H.$$

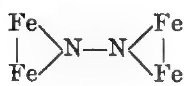
Heated similarly to 200° with phenol no reaction occurred.

Treated with a mixture of hydrogen peroxide and sulphuric acid, analyses showed that very little, if any, of the nitrogen is oxidised, the whole dissolving as usual to form ammonium sulphate.

In conjunction with Mr. P. J. Hartog, the author has determined the heat of formation of the nitride by dissolving it in sulphuric acid contained in a platinum calorimeter, and observing the rise of temperature. Three well-agreeing experiments showed that the substance is formed with evolution of about three calories.

In general the nitride of iron behaves as an ammonia derivative, the nitrogen being either evolved in the free state, or converted into ammonium compounds, according to circumstances.

Its constitution may possibly be



5. *Report on the Silent Discharge of Electricity in Oxygen and other Gases.* See Reports, p. 439.

FRIDAY, SEPTEMBER 15.

The following Reports and Papers were read:—

1. *Report on the Action of Light upon Dyed Colours.*—See Reports, p. 373.

2. *Demonstration of the Preparation and Properties of Fluorine by Moissan's Method. By* Dr. M. Meslans.

3. *Interim Report on the Formation of Haloids.*

The Committee desired reappointment, as their work is unfinished.

4. *Report on the Action of Light on the Hydracids of the Halogens in the Presence of Oxygen.*—See Reports, p. 381.

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5. *On the Iodine Value of Sunlight in the High Alps. By* Dr. S. RIDEAL.

During the past winter, at St. Moritz, in the Engadine, I had an opportunity of determining the intensity of the light as measured by the liberation of iodine from an acidulated solution of potassium iodide on the lines formulated by the Air Analysis Committee of Manchester. St. Moritz is at an altitude of about 7,000 feet above the sea level, and a succession of bright, sunny days can usually be relied upon, even in the depths of winter. The experiments in England, which have been carried out chiefly in towns, have not given a maximum value for the quantity of iodine that can be liberated by sunlight in one hour; and as the atmosphere in St. Moritz is not only free from haze, but is also remarkable for its exceptionable dryness, higher values than those likely to be obtained elsewhere were to be expected. Also, since the daily meteorological conditions of the place are carefully taken and recorded in the 'Alpine Post,' the observations may possibly be of additional value.

Date	No. of Hours	Total Mgms. Iodine per 100 c.c.	Hour Value	Conditions
1893, 1. .	3·5	47·25	13·5	Clouds, but bright
2. .	5·0	33·75	6·6	Dull all day
3. .	4·25	29·7	6·9	Sun one hour
4. .	4·20	37·8	8·8	Dull, then sun
5. .	4·0	39·0	9·75	Bright
6. .	4·0	41·85	10·46	Bright
7. .	6·0	43·2	7·2	Sun down two hours
8. .	5·0	41·85	8·37	Bright
9. .	4·35	41·85	9·45	Bright
10. .	5·5	32·4	5·9	Dull
11. .	4·5	37·8	8·4	Bright two hours
12. .	6·0	36·45	6·0	Bright
13. .	5·5	45·9	8·3	Bright
14. .	4·25	27·0	6·3	Dull
15. .	5·5	28·35	5·1	Bright, then dull
16. .	5·0	47·25	9·45	Slight snow
17. .	5·0	28·35	5·7	Bright
18. .	8·0	51·3	6·4	Bright, sun down three hours
19. .	4·3	36·45	8·4	Bright
20. .	6·0 (2 expts)	34·85	10·35	Bright
22. .	5·5	40·5	7·3	Snowing all day
23. .	—	—	—	Snowing hard
24. .	7·0	40·0	5·7	Dull
25. .	4·0	40·5	10·1	Bright
26. .	9·5 (2 expts)	93·1	9·8	Bright
27. .	4·2	53·3	12·7	Bright
28. .	7·0	58·5	8·3	Bright, then dull
29. .	6·0	52·0	8·8	Bright
30. .	4·5	50·7	11·2	Bright
31. .	6·0	50·7	8·4	Bright

The instructions laid down by the Air Analysis Committee were carefully followed, and the solution of iodine taken as a standard was titrated with great care. The hyposulphite solution was checked against the standard iodine solution from time to time, and was kept in the dark when not in use. The only previous values obtained in Switzerland in the winter are those of Professor Oliver, who tells me that his winter average at Grindelwald for one hour's sunlight was represented by 1·6 c.c. of the thiosulphate solution, equal to 8 mgms. of iodine per

100 c.c. This number represents only the average of the brightest days, and larger results have been obtained in summer. My average for the nineteen brightest days in January of the present year is equal to 9·34 mgms. of iodine per 100 c.c. per hour. Owing to the situation of the village with regard to the surrounding mountains, the total amount of light per day is small compared with places which are less shut in; and, as will be seen from the accompanying table, the values given are for the hours during which there was a bright sunlight. The actual amount of possible sunlight on the days mentioned will be found in the meteorological records already referred to. It is interesting to note that in Manchester in January 1892, with a day of 8·3 hours' light, or nearly half as long again as at St. Moritz, the total light per week-day averaged only 4·5 mgms. iodine, or about that obtained during half an hour's exposure at St. Moritz. Even on comparing the Sunday values for the Manchester district, I find that the *daily* average is only 8·3 mgms., or less than the hour's average at St. Moritz. I believe that the comparatively large amount of sunlight per day experienced in the High Alps contributes largely in determining the hygienic value of a sojourn in these mountain health resorts.

The maximum hour value was 13·5 mgms. per 100 c.c. on January 1, and the lowest on January 24 of 5·7, and even this minimum was about 20 per cent. above the average *daily* value in Manchester.

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6. *On a Modified Form of Bunsen and Roscoe's Pendulum Actinometer.*[1] *By* Dr. ARTHUR RICHARDSON *and* J. QUICK.

In Bunsen and Roscoe's pendulum actinometer the oscillations of a pendulum cause a sliding shutter to pass backward and forward before sensitised paper, which is thus exposed for a known time and again shaded from the light.

In the present form an arrangement has been devised whereby the backward and forward motion of the shutter is brought about by a movement in one direction only.

This is done in the following manner: the shutter, which is made of a flexible material and in the form of an endless band, passes over the wooden rollers, the adjacent surfaces being brought close together by means of two additional smaller rollers. Two slits of equal length are cut in the band, so that when the latter rotates an aperture is uncovered when the slits overlap one another, and which again close when the band has travelled round a certain distance.

Beneath this aperture the sensitised paper is placed, which is thus exposed for definite times depending upon the length of the slits and the velocity of the band.

In order to bring about the movement of the shutter one of the rollers is connected with an eight-day clock, the escapement of which has been removed, the alterations in the speed, usually occurring when a clock is running down under such circumstances, being compensated by a fusee adjustment.

Two advantages are claimed for this modification:—

(1) It is portable, and measurements can be made when it is placed in any position.

(2) The time during which any portion of the slit is open (over the sensitised paper) is directly proportional to that occupied in opening the entire slit; since the rate at which the shutter moves is constant, whereas in the pendulum apparatus a series of calculations must be made to determine the length of time during which the slit is open for each mm. of its entire length.

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7. *On the Expansion of Chlorine Gas and Bromine Vapour under the Influence of Light.* *By* Dr. ARTHUR RICHARDSON.

It was first observed by Budde that when chlorine is exposed to the influence of sunlight, an expansion of the gas occurs which is independent of the

[1] Published in the *Phil. Mag.*, xxxvi. (1893), pp. 459–463.

direct heating effects of the light. He also made a similar observation in the case of bromine vapour. These statements have been repeatedly called in question by other observers, who failed to obtain these results on repeating Budde's experiments.

Experiments made by the author, however, fully confirm Budde's results, and an arrangement is described in which the expansion of chlorine and bromine, as compared with that of air, under the influence of light, can be exhibited as a lecture experiment.

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8. *On the Cause of the Red Colouration of Phenol. By* CHARLES A. KOHN, *Ph.D., B.Sc., Lecturer on Organic Chemistry, University College, Liverpool.*

The cause of the turning red of phenol has from time to time been the subject of investigation, but the published results are vague and conflicting. That even the purest carbolic acid of commerce becomes coloured on keeping has long been observed, and the general view of the cause of this colouration has been to trace it to some impurity or other contained in the phenol. By some the presence of a metal, especially copper or iron or their salts, has been regarded as the cause of the reddening, by others the colcuration has been attributed to alkalis or to cresol, which last in presence of the phenol has been oxidised with the formation of rosolic acid. Fabini, who more recently has investigated the subject, regards the colouration as due to the action of hydrogen peroxide on phenol containing metallic salts in presence of ammonia, the presence of all three reagents being necessary for the production of the colour.

Since oxidising agents, alkalis—especially ammonia—and metallic salts play an important part in the turning red of phenol, the action of these and similar reagents on phenol of varying degrees of purity was tried.

The phenol used was the purest commercial product known as '*absolute phenol*,' and in the later experiments a sample of specially pure phenol, kindly prepared by C. Lowe, Esq., of Manchester. The original product was repeatedly distilled from glass vessels and the distillates after one, six, nine, and sixteen distillations carefully tested with ammonia, hydrogen peroxide, caustic potash, mixtures of these reagents, and also with salts of iron and of copper both in the presence and absence of alkalis and of hydrogen peroxide. In all cases characteristic colourations ensue. That with strong ammonia is violet, and those with hydrogen peroxide, caustic potash, dilute ammonia, hydrogen peroxide in presence of caustic alkali, or of ammonia, metals or metallic salts with or without hydrogen peroxide, red or reddish brown. Each of the three reagents which, according to Fabini, must all be present in order to produce a colouration gives marked colourations on its own account. The blue colouration obtained with ammonia is identical with Phipson's 'phenol-blue,' and is probably phenol-quinone-imide. Sublimed phenol, as well as phenol prepared by the saponification and subsequent decomposition of gaultheria oil, behaves similarly.

Furthermore, *all* the samples thus prepared, and which were found on testing to be perfectly free from metallic impurities, turned red on exposure to ordinary moist air. Hence it is to be concluded that the purest phenol does redden of its own account, and not on account of the presence of impurities of any kind. This reddening does not take place in the dark, nor is it effected by the less refrangible rays of light. Phenol exposed in vacuo keeps colourless for months, as it also does when exposed in presence of water in absence of air, or in presence of air when perfectly dry. Both air and moisture are necessary for the colouration to ensue. It has been shown by Dr. Richardson that hydrogen peroxide is produced during the reddening, and to its formation the reddening of phenol when exposed to ordinary moist air is to be traced. The similarity of the colour produced by hydrogen peroxide with that which phenol assumes on exposure supports this statement. The colour is also produced by the electrolysis of phenol in acid solution. The colouring matter is not volatile, and the colouration is always accompanied by the absorption of moisture.

The nature of the colouring matter produced is still under investigation; the essential point so far established is that pure phenol possesses the intrinsic property of reddening when exposed to light in presence of air and moisture.

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9. *On the Rate of Evaporation of Bodies in Atmospheres of Different Densities. By* Dr. R. D. Phookan.

The results of his experiments showed 'that under the same conditions of heat and pressure a substance volatilises more quickly in an atmosphere of *gas* of lesser density than in one of greater. For instance, 0·05 grm. of naphthalin, heated in a bath of naphthalin vapour, volatilised in an atmosphere of hydrogen gas in 18 seconds, in air in 30, in carbon dioxide and nitrous oxide, both of which possess the same molecular weight, in 36 seconds.

Although these figures do not furnish sufficient data to determine the relative densities of the gases, yet they amply justify the above conclusion.

An atmosphere of *vapour*, on the contrary, seems to have no influence on the time taken for a substance to volatilise in it: 0·026 grm. of normal propyl alcohol, heated in a steam bath, took one and the same time, 12 to 13 seconds, to volatilise in vapours of such different densities as that of ether, methyl, and ethyl alcohol, chloroform, tetrachlor-methan, and ethyl iodide.

It is difficult to account for this anomaly. A certain difference in conditions in the employment of the two classes of bodies—*i.e.*, the true gases and the vapours—must, however, be borne in mind, namely, that the *gases* were experimented with at a temperature much more removed from their point of condensation than that of the *vapours*.

It will be therefore interesting to know whether experiments made with vapours at a temperature equally removed from their point of condensation would not give results similar to those obtained from gases.

It may be that a vapour must attain a certain degree of energy or velocity of its molecules before it can act like true gases in influencing the volatilisation of a substance.

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10. *On the Occurrence of Cyano-nitride of Titanium in Ferro-manganese. By* T. W. Hogg.

In this paper is given a short account of the fact there are probably about half a million isolated crystals of cyano-nitride of titanium in each cubic inch of the high percentage ferro-manganese now used for steel-making purposes, titanium carbide and nitride being also occasionally present.

The size of these crystals generally lies between 0·0001 and 0·001 of an inch, comparatively few of them being larger than this.

The number of crystals has been counted, and the lowest estimate gave 336,000 to the cubic inch of alloy; as a matter of interest, the weight of this number of cubes of cyano-nitride of titanium of 0·0001 of an inch has been calculated and found to be only 0·00003 of a gramme. Similarly, the weight of the same number of cubes of 0·001 of an inch weighs ·03 gramme. The crystals are possessed of a high metallic lustre with brilliant mirror-like facets, and occur in the form of cubes, octahedra, and forms resembling the icositetrahedron; there are also present beautiful combinations of pyramids and prisms, and many of the cubes possess interesting symmetrical face modifications. As these different forms are all found together they are microscopic objects of great beauty and interest to the student of crystallography. These crystals are obtained by careful elutriation of the carbonaceous residue left after treating considerable quantities of the ferro-manganese with hydrochloric acid, cupric chloride, or dilute nitric acid: this latter is recommended as being the most convenient. In using it the mixture must be kept as cool as possible, and allowed to stand for about twenty-four hours; the larger crystals separate at once, the smaller forms being retained in the residue, which must be dried and gently pounded before submitting it to elutriation. This is best

performed in a large porcelain basin, using plenty of water, gently rocking and rotating the mixture, and allowing it to rest at intervals; the lighter portions are then sucked up by means of a pipette, this being continued until nothing but the copper-coloured crystals are left.

The largest quantity which has been separated in this way is equal to ·032 per cent.

Ferro-manganese containing different percentages of manganese and of different makes has been examined, and, with the exception of spiegeleisen containing 11 per per cent. of manganese, they have all been found to contain this remarkable compound.

As the quantities available for examination were small, with the exception of determining the specific gravity and the amount of the titanium only qualitative tests have been applied. In different specimens the specific gravity has been found to vary between 4·1 and 5·1, and the titanium from 60·5 to 79·8 per cent. These latter determinations include a small proportion of iron, which I have always found to be present; this is also the case with crystals separated from an old blast-furnace 'bear.' After several days' heating with hydrochloric acid there is 1·5 per cent. iron retained, and probably this is the cause of the crystals being slightly but distinctly magnetic.

Attention is specially directed to the fact that much valuable information with regard to the condition of the foreign elements may be obtained by decomposing large quantities of the alloys with suitable reagents, and separating the substances of different specific gravity from the residue. In doing this it is pointed out that there is great danger of decomposing the compounds originally present, and forming new ones as a result of the reaction which takes place between the reagent and the various substances present. Such a method as is indicated in this paper is recommended to be used in conjunction with the examination of etched specimens, which of themselves do little beyond revealing changes of structure induced by different modes of manipulation and varying temperatures. The insufficiency of etched specimens to give us information with regard to the condition of impurities is evident from the fact that, being opaque, so nearly alike in colour, and in such minute and uniformly distributed particles, they escape observation.

SATURDAY, SEPTEMBER 16.

The Section did not meet.

MONDAY, SEPTEMBER 18.

The following Reports and Papers were read:—

1. *Interim Report on the History of Chemistry.*

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2. *Report on the Wave-length Tables of the Spectra of the Elements.*
See Reports, p. 387.

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3. *Interim Report on the Bibliography of Spectroscopy.*

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4. *Report on the Bibliography of Solution*—See Reports, p. 372.

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5. *Report on Solution.*—See Reports, p. 438.

6. *A Discussion on the Present Position of Bacteriology, more especially in its relation to Chemical Science, was opened by* Professor PERCY F. FRANKLAND, *F.R.S.*

Professor FRANKLAND'S paper was ordered to be printed *in extenso* among the Reports.—See Reports, p. 441.

7. *Remarks on the Chemistry of Bacteria. By* R. WARINGTON, *F.R.S.*

8. *On Fermentation in the Leather Industry. By* J. T. WOOD.

The science of bacteriology touches upon the leather industry in the following important points:—

1. Putrefaction.
2. The Soaks.
3. Changes in lime liquors.
4. Bating or 'Puring.'
5. Drenching.
6. Fermentation of tan liquors.

The author only gave a short *résumé* of our present knowledge of the 'drenching' process, as this closely resembles ordinary fermentations.

Skins from the bate after washing are placed in vats containing an infusion of bran in water (0·4 to 1 per cent. of bran) at a temperature of 30° to 35° C. This ferments vigorously for eighteen to twenty-four hours with evolution of considerable quantities of gas and the formation of weak organic acids, which have a slight swelling action on the skin, cleanse the pores, and make it in a fit condition to receive the tannin. On examination with a high power of the microscope the liquid is found to be swarming with active bacteria. They are mostly in the form of pairs or dumb-bells, each cell $0{\cdot}75\mu \times 1{\cdot}25\mu$; some form chains. I described [1] a method by which the organism causing the fermentation was separated, as it refused to grow in ordinary nutrient gelatine, and lately, in conjunction with Mr. W. H. Willcox, B.Sc., have made a complete examination of the products of the actual fermentation as it takes place in the works, previous to carrying out a similar research with the pure ferment.

We found the following gases evolved:—

Gases	A	B	C
CO_2 and H_2S	21·9	25·2	42·4
O_2	1·0	2·1	3·6
H_2	53·1	46·7	28·2
N_2	24·0	26·0	25·8

A is from a vat containing no skins, one to two days.
B from a vat containing skins, two to three days.
C from a vat containing skins, three to four days.
The H_2S is present only in small quantities (1 to 2 per cent.).

The principal acids found were acetic acid and lactic acid, accompanied by small quantities of formic acid and butyric acid.

The following table shows the quantities found in an experimental drench per 1,000 c.c.:—

[1] *Journ. Soc. Chem. Ind.*, ix. 27.

	Gramme.
Formic acid	0·0306
Acetic acid	0·2402
Butyric acid	0·0134
Lactic acid	0·7907
Total	1·0749

We find in actual work that the quantity of acid produced varies from one to three grms. per litre.

We found that an unorganised ferment, 'cerealin,' changes the starch of the bran into glucoses and dextrin; the bacteria then ferment the glucoses, splitting them up into the gases and acids already mentioned.

B. furfuris has no action on the cellulose of the bran, nor on the skins, as some bacteria in the bate have; in every case where the skin is attacked it is putrefactive or gelatine liquefying bacteria introduced from the bate, or in specially favourable circumstances (hot, sultry weather) developing from germs always present in the atmosphere. The gases evolved have only a mechanical action on the skin, floating and distending them, and so enabling them better to take up the acids. In carrying out this work we discovered a delicate test for lactic acid.

The presence of lactic acid was shown in the following manner:—10 c.c. of the liquid were placed in a small distilling flask along with 2 c.c. strong H_2SO_4 and about 0·5 grm. potassium chromate in a little water. This was distilled and the vapours received in a test tube surrounded by cold water; on adding magenta solution discolourised by SO_2 to the liquid in the test tube a red colour was produced by the aldehyde formed from the lactic acid; aldehyde was also recognised by its smell. We find this an exceedingly delicate test for lactic acid, and as far as we know it is quite new in this form.

For 10 c.c. of liquid to be examined we find 2 c.c. strong H_2SO_4 and 1 grm. of potassium chromate to be the best proportions. Formic, acetic, propionic, butyric, valerianic, succinic, malic, tartaric, and citric acids do not give the reaction.

In conclusion, there are no doubt other organisms capable of fermenting a bran infusion in a somewhat similar way, and the work of isolating and separately examining their life-history and products yet remains to be done.

9. *On some Ferments derived from Diseased Pears.* *By* GEORGE TATE, *Ph.D., F.C.S.*

From diseased pears the author has isolated, among other micro-organisms, three which possess morphological and chemical interest.

(1) A yeast (*Saccharomyces viscosus*) which is characterised by forming small cells of an average length of 0·003 mm. and white, strongly viscid growths upon solid nutrient media. It brings about no alcoholic fermentation of the better-known sugars, but inverts cane sugar. It can propagate either by budding or by endogenous division.

(2) A bacterial organism (*Ascococcus luteus*) forming yellow growths upon nutrient gelatine. Growths of two types have been obtained, one showing *ascococci*, the other only rods. It is an acid ferment of dextrose and mannitol.

(3) A bacterial organism forming white growths upon nutrient gelatine. Two types of growth have been obtained upon nutrient media, one in which *micrococci* and rods predominate, another in which the tendency to form *ascococci* is strongly marked. These two types are represented by widely differing macroscopic cultures upon solid media. Both forms behave as lævo-lactic ferments towards dextrose and mannitol.

The organism is an inactive-lactic ferment of rhamnose, but after such action still retains its power of decomposing dextrose into lævo-lactic acid.

10. *On the Action of Permanganate of Potassium on Sodium Thiosulphate and Sulphate.* *By* G. E. Brown *and* Dr. W. W. J. Nicol.

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11. *On the Application of Sodium Peroxide to Water Analysis.* *By* Dr. S. Rideal *and* A. J. Boult.

Now that sodium peroxide can be obtained commercially, its use in analysis seems desirable. W. Hempel[1] has already shown that it is a useful oxidising agent for the detection of chromium and manganese, and that it forms a very convenient reagent for opening up tungsten minerals and for effecting the decomposition of titanic iron ores. Since the commercial sodium peroxide is free from sulphur, it can also be used quantitatively for estimating the sulphur in sulphides. It occurred to us that an alkaline oxidising agent of this character, if used as a substitute for alkaline permanganate in water analysis, might throw some light upon the character of the organic nitrogen in waters. Hitherto either methods for determining the total nitrogen—*e.g.*, Frankland's and Kjeldahl's, or Wanklyn's well-known process in which only a portion of the nitrogen present in the organic matter is discovered—have been employed. In this latter process very different quantities of ammonia are obtained from the different classes of nitrogenous organic bodies. Only when the nitrogen is present as some simple amido- compound like urea, aspartic acid, or leucine does this process yield the whole of the nitrogen present. Preusse and Tiemann[2] have shown in their review of the various processes for determining organic substances in water that no reliance can be placed upon this process for estimating the absolute quantity of nitrogen in many substances, and that, therefore, when used as a method of water analysis the quantities of ammonia obtained are only relatively true for waters of the same type. A comparison of the quantities of ammonia evolved from a water when treated with alkaline permanganate and with sodium peroxide might therefore possibly afford a means of differentiating the nitrogenous constituents. With this purpose in view we have compared in the ordinary course of analysis the amounts of ammonia given off under these two treatments. In one case when using one grm. of sodium peroxide per half litre of water, the total ammonia evolved was equal to 0·027 part per 100,000, while with alkaline permanganate 0·050 part per 100,000 was obtained. On repeating this experiment with the same water and under similar conditions, 0·026 part per 100,000 was yielded by the peroxide and 0·048 by the permanganate. The addition of a further quantity of the sodium peroxide and further distilling did not increase the quantity of ammonia produced, and it was therefore evident that the sodium peroxide had failed to break down the organic nitrogenous substances present to the same extent as had the alkaline permanganate. In fact, we have since found it possible to obtain a fresh quantity of ammonia from a water after treatment with sodium peroxide by the addition of the alkaline permanganate. The following table gives the results obtained in parts per 100,000 with four samples of water:—

—	Free NH_3	Peroxide	Permanganate after peroxide	Free NH_3	Permanganate
Water A	0·01	Trace	0·007	0·01	0·008
,, B	0·001	0·004	0·011	0·001	0·013
,, C	0 012	0·011	0·015	0·012	0·027
,, D	0·021	0·024	0·057	0·019	0·078

From these figures it will be seen that the sodium peroxide in no case oxidises the organic matter present to the same extent as does the permanganate. The peroxide seems to liberate a portion of the nitrogen which is included in that set free by the alkaline permanganate, as the total ammonia obtained by the action of

[1] *Zeit. anorg. Chem.*, 3, 193.

[2] *Berichte*, 12, 1906.

the peroxide, followed by permanganate, is in most cases about equal to that obtained when the water is distilled with alkaline permanganate alone. There appears to be no ratio between the quantities of ammonia evolved by the two reagents, and therefore the nitrogenous organic matter present in waters might be divided into two classes, viz., that which is oxidised by the sodium peroxide and that which resists such treatment. The results obtained by Wanklyn's process, as compared with the total nitrogen present in a water, also show a differentiation in the organic nitrogen substances present in waters, but this knowledge has hitherto not been of any value owing to the complex nature of the problem. Further experiments can alone decide whether the limited oxidation of the nitrogenous matter in waters will throw any fresh light on the condition of these organic constituents of water. We have, however, noticed that in some cases a water which has been partially oxidised by the peroxide yields the remainder of its ammonia to the alkaline permanganate with much greater rapidity than when the water has not been so treated. We suggest that the explanation of this phenomenon may be due to the presence in waters of organic nitrogenous substances which, when partially oxidised, are then in a condition to be completely broken up by the stronger reagent. This result has been obtained with waters containing fresh sewage, but we hope by taking solutions containing nitrogenous compounds of known constitution to confirm this suggestion, and to show that in this reagent we have an oxidising agent which will be useful in establishing the constitution of the nitrogen in complex organic substances.

TUESDAY, SEPTEMBER 19.

The following Reports and Papers were read:—

1. *Report on Isomeric Naphthaline Derivatives.*—See Reports, p. 381.

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2. *On the Application of Electrolysis to Qualitative Analysis. By* CHARLES A. KOHN, *Ph.D., B.Sc., Lecturer on Organic Chemistry, University College, Liverpool.*

Since the publication of C. Bloxam's papers on 'The Application of Electrolysis to the Detection of Poisonous Metals in Mixtures of Organic Matters'[1] little has been done to apply this method of analysis to qualitative investigations, despite the fact that Classen and his pupils, together with E. F. Smith and others, have made rapid advances in electrolytic methods of quantitative analysis. Many of these later methods offer special attraction for qualitative work, especially in cases of medical and of medico-legal inquiry. They are not supposed to supersede in any way the ordinary methods of qualitative analysis, but to serve as a final and crucial means of identification for the more important mineral poisons. The applicability of the methods for the detection of antimony, mercury, lead, copper, and cadmium has been examined. The method originally devised by Bloxam for the detection of arsenic has been more recently elaborated by Wolff, who has succeeded in detecting 0·00001 grm. of arsenious acid electrolytically.

Antimony.—The method employed is that used in the quantitative estimation by electrolysis, a method devised by Classen, and which ensures a complete separation from antimony and tin. The precipitated sulphide is dissolved in potassium sulphide, any polysulphides present oxidised with hydrogen peroxide, and the solution electrolysed with a current of 1·5–2·0 c.c. of electrolytic gas per minute (10·436 c.c. at 0° and 760 mm. = 1 ampère), a small circular piece of platinum 1 cm. in diameter being employed as the cathode. The deposited metal can be confirmed for by evaporating a little ammonium sulphide on the foil. One part of

[1] *J. Chem. Soc.*, **13**, pp. 12 and 338.

antimony in 1,500,000 parts of solution may be thus detected. The precipitation of small quantities is complete in one hour.

Mercury is separated from a nitric acid solution as metal, on a small closely-wound platinum spiral. A current of 4–5 c.c. per minute can be used. As a confirmatory test the spiral is washed, dropped into a test-tube, heated to sublime the mercury, and then converted into the iodide by the addition of a small crystal of iodine and warming gently: 0·0001 grm. of metal can be detected thus in 150 c.c. of solution.

Lead is precipitated either as peroxide at the anode from a nitric-acid solution or as metal from an ammonium-oxalate solution; the latter method is more delicate, but the former has the advantage that it can be made approximately quantitative. In this case also 0·0001 grm. is readily detected, the confirmation being effected by converting the metal or oxide into the sulphide or iodide.

Copper is electrolysed as usual from an acidified solution, and 0·00005 grm. can be readily detected, the confirmation being effected by dissolving the precipitated metal in acid and testing with potassium ferrocyanide. Quantitative results with 1 mgrm. of metal are obtained thus.

Cadmium is best deposited from a potassium cyanide solution, with a current of 0·2 c.c. per minute. The yellow sulphide serves as the confirmatory test: 0·0001 grm. of metal can be thus detected.

The detection of the above metallic poisons in urine can be effected directly by these methods as described, but owing to the presence of the organic matter it is necessary to pass the current twice as long as when aqueous solutions are employed. In twenty-four hours a current of 1–2 c.c. per minute completely decomposes urine, leaving a clear solution. In the case of lead the electrolysis of an ammonium-oxalate solution gives a more delicate reaction than the separation as peroxide from nitric acid solution. To detect these poisons in other cases the destruction of the organic material with which they are associated, by the ordinary means, is necessary.

These electrolytic tests are one and a half time more delicate than the colorimetric tests for antimony and copper by means of sulphuretted hydrogen, and ten times more delicate than the tests for mercury and lead by the same reagent.

It is further to be noted that the methods are in many cases methods of separation as well as of detection, *e.g.*, the separation of lead from iron by electrolysis in nitric acid solution. Also where it is desirable to obtain approximately quantitative results, electrolysis possesses a marked advantage over the usual colorimetric processes, because the erroneous results due to the influence of the varying constituents in the solutions tested on the reliability of the reaction are entirely obviated.

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3. *Interim Report on the Proximate Constituents of Coal.*

The Committee desired reappointment, as their investigations are not yet completed.

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4. *Apparatus for Extraction for Analysis of Gases Dissolved in Water. By* EDGAR B. TRUMAN, *M.D., F.C.S., Borough Analyst, Nottingham.*

A glass flask of 500 c.c. capacity is joined by means of its tubular termination to a second lower flask of 200 c.c. capacity by means of a water-joint. In the lower flask is suspended from the upper one a thermometer, reading up to 150° C. From the neck of the upper flask proceed two millimetre tubes. The right-hand one, after receiving a stopcock, expands into a cup having a capacity of 30 c.c. The tube on the left rises to the level of the bottom of the cup. This tube has two tubes supplied with stopcocks joined on to it at right angles—one above and the other below. To the one above is attached, by a water or glycerine joint, a mercury tube doubled on itself above and below, and having a length when so doubled of 880 mm. This tube is graduated in mm. from 0 to 400 in two directions, downwards in the open limb and upwards

in the long limb, starting in each case from the level of the horizontal tube. This tube is filled with mercury up to the zero points, and indicates the rate of exhaustion of the apparatus, and is also a test of leakage.

The second tube a little further on points downwards for attachment to a Geissler's water-pump. Still further on a stopcock is let into the main horizontal tube, which then bends downwards for communication with a Sprengel pump.

The apparatus is put into connection with both mercurial and water-pumps, and the stopcock at the base of the cup is closed. By means of the water-pump the apparatus is exhausted in a great measure of air; five minutes' pumping with high-pressure water produces a vacuum of 730 mm., when the barometer stands at 753. The water-pump stopcock is then closed, and exhaustion is completed by the Sprengel in about thirty minutes more.

The liquid to be examined for gases is then, after measurement, introduced by the cup into the upper flask, whence it flows into the lower one.

The liquid is allowed to stand for an hour, so that gases disengaged at ordinary temperatures may come off. These are collected by the Sprengel and analysed in the usual way.

The vacuum having been restored, heat is cautiously applied to the lower flask by means of a Bunsen burner. If carefully done there is no bumping. The effect of heat is, by disengaging gas, to increase tension, and to enable the water to become hotter. The mercury in the mercurial tube and that in the thermometer rise. When the mercury in both places remains constant the Bunsen burner is removed.

The gas given off by boiling is then collected and analysed.

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5. *A Discussion on Explosions in Coal Mines, with special reference to the Dust Theory, was opened by* Professor H. B. Dixon, *F.R.S.*

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6. *The Application of the Hydrogen Flame in an Ordinary Miner's Safety Lamp to Accurate and Delicate Gas Testing. By* Professor Frank Clowes, *D.Sc. Lond.*

The 'flame cap' or halo seen in the dark above a pale flame in air containing combustible gas serves as the most rapid and practical means of detecting the presence of inflammable gas or vapour in the air. The method has been in common use by the miner, but the oil flame which he uses for the purpose is wanting, not only in delicacy, but also in accuracy. It will not readily detect the presence of less than 3 per cent. of fire-damp in the air, whereas for modern purposes it should detect less than 0·5 per cent.; and, owing to the variation in the size and adjustment of this flame when applied to testing, its indications are very variable, and are not of a standard character. Many objections exist to the employment of a separate alcohol lamp carried for testing purposes. None of these applies to the use of the hydrogen flame, especially when it is applied in an ordinary safety lamp burning oil from a wick in the usual way. The hydrogen flame is the most delicate indicator known, and it is applied of uniform size, giving standard and invariable indications.

The author's early work consisted in measuring with accuracy the height and noting the appearance of the flame cap appearing over the standard 10 mm. (= 0·4 inch) hydrogen flame. The flame was exposed for this purpose to air containing known percentages of gas in the 'test chamber' specially devised for the purpose. The statement, previously made, that the hydrogen flame is the most delicate gas-testing flame known was fully confirmed by comparing its indications with those yielded by a small alcohol flame and by a reduced oil flame. The small alcohol flame could not detect less than 1 per cent. of fire-damp, even under the most favourable conditions; the reduced oil flame could not detect with certainty less than 3 per cent.

The author then directed his attention to applying the hydrogen flame in a

practical way to the detection and measurement of minute quantities of fire-damp in the air. This was ultimately effected by supplying the hydrogen from a small steel cylinder containing the gas in a compressed condition. The cylinder can be readily carried in the pocket, and, when necessary, it can be immediately attached to the ordinary safety lamp, and made to furnish the standard hydrogen flame burning at a jet in the lamp. The gas is kindled at the jet by the oil flame, which is then extinguished. The accurate estimation of proportions of fire-damp in air varying from 0·2 to 3 per cent. is rapidly and easily effected by the standard hydrogen flame. Higher percentages are estimated either by reducing the size of the hydrogen flame, or by employing the oil flame diminished in size until it becomes non-luminous.

The small pocket cylinder is under a pound in weight, and when freshly charged, by being connected with a store cylinder at 120 atmospheres' pressure, it carries a store of gas sufficing for over 200 tests. This combined lighting and testing safety lamp has been found to be thoroughly practical in its nature after lengthened use in several collieries, and it surpasses in convenience all the delicate and accurate mine gas-testing apparatus yet described. The lamp, in a modified form, has been adapted to detecting and measuring petroleum vapour in the air.

7. *On the Gases enclosed in Coal Dust. By* Professor P. P. Bedson.

8. *A Note on the Temperature and Luminosity of Gases. By* Professor A. Smithells.

9. *On Ethyl Butanetetracarboxylic Acid, and its Derivatives. By* Bevan Lean, *B.A., B.Sc., Bishop Berkeley Fellow of Owens College.*

When sod-malonic ether is treated with ethylene bromide, the chief product is *ethyl trimethylene dicarboxylate* (1·1), thus:—

$$\begin{matrix} CH_2Br \\ | \\ CH_2Br \end{matrix} + 2CHNa:(COO\ C_2H_5)_2 = \begin{matrix} CH_2 \\ | \\ CH_2 \end{matrix}\!\!>\!C=(COO\ C_2H_5)_2 + CH_2(COO\ C_2H_5)_2 + 2NaBr.$$

But at the same time a small quantity of an oil of high boiling-point is formed, constituting only about 3 per cent. of the whole, which is *ethyl butanetetracarboxylate,*[1] thus:—

$$\begin{matrix} CH_2Br \\ | \\ CH_2Br \end{matrix} + 2CH\ Na:(COO\ C_2H_5)_2 = \begin{matrix} CH_2-CH:(COO\ C_2H_5)_2 \\ | \\ CH_2-CH:(COO\ C_2H_5)_2 \end{matrix} + 2NaBr.$$

The fact that this interesting substance is produced in such small quantities made its further investigation a matter almost of impossibility. More recently, however, Professor Perkin has found that the substitution of ethylene chloride for the bromide is effectual in greatly increasing the yield of ethyl butanetetracarboxylate. As soon as the new method for the preparation of this substance had been thoroughly worked out, I investigated, at the suggestion of Professor Perkin, some of its derivatives, and I desire to give a brief notice of some of the results at which we have arrived. When treated with sodium ethylate, ethyl butanetetracarboxylate forms a di-sodium compound, which reacts readily with the iodides or chlorides of the alcohol radicals. For example, when acted on by methyl iodide the reaction takes place as follows:—

$$\begin{matrix} CH_2-CNa:(COO\ C_2H_5)_2 \\ | \\ CH_2-CNa:(COO\ C_2H_5)_2 \end{matrix} + 2CH_3Br = \begin{matrix} CH_2-C{\cdot}CH_3:(COO\ C_2H_5)_2 \\ | \\ CH_2-C{\cdot}CH_3:(COO\ C_2H_5)_2 \end{matrix} + 2NaBr,$$

ethyl dimethylbutanetetracarboxylate being formed.

[1] Perkin, *Journ. C. S.*, 51, 1.

In the course of this investigation I have already made a detailed study of the di-methyl, di-ethyl, di-cetyl, and di-benzyl derivatives of ethyl butanetetracarboxylate, formed by the action of alcohol radicals on its di-sodium compound.

These derivatives on hydrolysis yield *tetracarboxylic acids*, which possess some very remarkable properties, which have not been, so far as I know, observed in the case of any other organic acids. These acids, although they contain four carboxyl groups, do not in all cases behave as tetrabasic acids. On determining their basicity by titration with standard solution of potassium hydrate, some of them react as di-basic acids. Notably is this the case with di-benzyl butanetetracarboxylic acid, the result being the same whether phenol phthalein or litmus be used as the indicator. In this connection it is to be noted that on forming the silver or calcium salts of di-benzyl butanetetracarboxylic acid, they were found to have the formulæ $C_{22}H_{20}O_8Ag_2$ and $C_{22}H_{20}O_8Ca + 2H_2O$ respectively. On the other hand, di-methyl and di-ethyl butanetetracarboxylic acid on titration with potassium hydrate give different results according as phenol phthalein or litmus is used as an indicator. They behave as tetrabasic acids when phenol phthalein is employed. If, however, one or two drops of litmus solution be added to the solution of these acids in potassium hydrate, which, as shown by phenol phthalein, had been neutralised by hydrochloric acid, a distinctly blue colouration is produced. On adding more hydrochloric acid the blue colouration changes gradually to a red tint, and the solution appears to become neutral to litmus, only when sufficient hydrochloric acid is added to neutralise one half of the potassium hydrate, which was equivalent, as shown by phenol phthalein, to the tetracarboxylic acid present. The silver salts of di-methyl and di-ethyl butanetetracarboxylic acid, unlike that of di-benzyl butanetetracarboxylic acid, are tetrabasic.

The di-substituted butanetetracarboxylic acids we have obtained, when heated to 200°, all lose two molecules of carbonic anhydride, yielding *di-substituted adipic acids.* The study of these acids appeared to be especially interesting in view of the recent work on the di-substituted succinic, and glutaric, and pimelic acids. In accordance with Van 't Hoff's theory, the di-substituted succinic and glutaric acids are found in two modifications. The substituted pimelic acids, on the other hand, have only been found in one modification.

Considerable interest is therefore attached to the question of isomerism in the substituted adipic acids. We have found that the di-substituted adipic acids, obtained from substituted butanetetracarboxylic acids, invariably exist in two modifications, which are readily capable of separation by crystallisation from benzene or toluene.

The difference between the melting points of the two modifications is usually 60–80°. For example, two modifications of di-benzyl adipic acid were isolated, one crystallising in diamond-shaped crystals, which melted at 211–3°, the other crystallising in six-sided prisms melting at 152°. Of these derivatives of adipic acid the di-methyl alone have been previously obtained. They were prepared by Zelinsky, by the hydrolysis of ethyl dicyandimethyl adipate.[1]

Experiments on succinic acid have shown that the more alkyl groups there are introduced, the more readily can an *anhydride formation* take place, and it was thought that this would also be the case in the adipic series. Now, the anhydride of adipic acid has been formed, yet on attempting to form anhydrides by heating the substituted adipic acids in sealed tubes with acetyl chloride, in no case could any evidence of an anhydride formation be obtained. On the other hand, whether the higher melting or lower melting modification was employed, a partial conversion into the other modification was effected. This result is remarkable, and cannot at present be understood.

The author has also formed *ethyl dibromobutanetetracarboxylate*, by the action of bromine on a solution of ethyl butanetetracarboxylate in chloroform. It crystallises in magnificent prisms, which melt at 82–3°. The author is engaged in the investigation of this substance, and expects interesting results from the study of its derivatives and its use in synthetical chemistry.

[1] *Ber.*, 24, ii. 997

10. *On the Salts of a new Platinum-sulphurea Base.* By W. J. Sell, *M.A., F.C.S., F.I.C.,* and T. H. Easterfield, *M.A.*

The authors have obtained the salts of a base $Pt(CSN_2H_4)_4(OH)_2$ by the action of platinic chloride upon a hot solution of thiocarbamide in dilute hydrochloric acid, and subsequent addition of the acid the salts of which are required. The chloride $Pt(CSN_2H_4)\,Cl_2$, sulphate $Pt(CSN_2H_4)_4SO_4$, and the picrate have been prepared and analysed.

The free base corresponding apparently to Reiset's first base $Pt(NH_2)_4(OH)_2$ has not yet been obtained pure, for its solutions undergo partial decomposition upon evaporation even in a vacuum. That the crystalline residue thus formed contains the base is evident from the fact that the above-mentioned salts can be regenerated from it.

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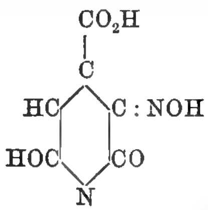
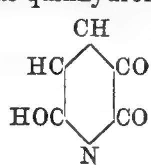
11. *On Citrazinic Acid.* By W. J. Sell, *M.A., F.C.S., F.I.C.,* and T. H. Easterfield, *M.A.*

A. W. v. Hofmann has shown that citrazinic acid is in all probability to be regarded as *a, a′* dioxyiso-nicotinic acid. In this paper it is shown that in a number of cases the tautomeric keto formula more readily represents the reactions of the substance. The chlorine, bromine, and isonitroso, and derivatives prepared with a view to testing the constitution are quite in accordance with the keto formula, whilst the phenylhydrazo derivative has not been sufficiently studied for the authors to decide its constitution. Isonitroso-citrazinic acid



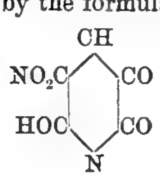
is a somewhat unstable substance, yielding a beautiful silver salt; when boiled with dilute sulphuric acid it yields quinhydroketopyridin



which on oxidation with dilute nitric acid yields the corresponding quinone, and by reduction appears to yield the hydroquinone which has not yet been obtained in the analytically pure condition.

The above-mentioned quinhydroketopyridin dissolves in alkaline solutions with the production of a deep-blue solution, and it appears to be to this cause that the characteristic 'nitrite' test for citrazinic acid is due. By the oxidation of isonitroso-citrazinic acid with nitric or nitrous acids a bright yellow acid results which gives very characteristic salts. The acid potassium and ammonium salts are precipitated in the crystalline condition by adding the chlorides of these radicles to an aqueous solution of the acid. Although the acid contains only two hydrogen atoms these are both replaceable by metals. Reduction of the yellow acid leads to the formation of the quinhydroketopyridin.

By the action of cold nitric acid upon citrazinic acid a substance is produced which appears to be represented by the formula



i.e., it seems to be a nitroquinoketopyridin; the calcium salt of this substance crystallises in beautiful yellow needles. Experiments are also in progress upon the products of reduction of citrazinamide. The reduction takes the same course as in the normal reduction of amides of the aromatic series, an alcohol being produced.

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12. *On a Nottingham Sandstone containing Barium Sulphate as a Cementing Material. By* Professor FRANK CLOWES, *D.Sc.*

The author draws attention to papers presented by him to former meetings of the British Association ('Brit. Assoc. Reports,' 1885, p. 1038, and 1889, p. 594). These papers described sandstone extending over a large area at Bramcote and Stapleford, in the immediate neighbourhood of Nottingham, in which crystallised barium sulphate occurred in large quantity. Bramcote and Stapleford Hills and the Hemlock stone were wholly composed of such stone. The largest quantity found in the specimens analysed reached 50 per cent.; complete analyses were given of specimens of sandstone from different parts of this district. The sulphate was in a beautifully micro-crystalline condition, and the crystals had been identified and separated both by Professor Lebour and by Mr. J. J. H. Teall. In some parts of the sandstone the barium sulphate uniformly permeated the mass. In other parts the sulphate occurred in streaks or network, the latter distribution leading to a curious mammillated weathering of the surface of the rock, owing to removal of the uncemented grains. Occasionally the cementing material occurred in nodular patches, as seen in sections of the sandstone: this led to the formation of the so-called 'pebble sand-beds' at the top of one of these sandstone hills. The beds were the effect of weathering; the uncemented sand-grains became loose sand, and disseminated amongst the loose sand were the 'pebbles,' consisting of masses of sand-grains bound together by barium sulphate. The author has not been able to obtain from any source evidence of the occurrence of similar sandstone in any other part of this country; he is still without direct evidence whether the sulphate has been deposited as such, as in the colliery boxes of Durham, or is the result of chemical change occurring between calcium sulphate in solution coming into contact with barium carbonate already deposited in the sandstone.

Section C.—Geology.

President of the Section.—J. J. H. Teall, M.A., F.R.S., F.G.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

It is a striking and remarkable fact that, although enormous progress has been made in petrographical science during the last hundred years, there has been comparatively little advance so far as broad, general theories relating to the origin of rocks are concerned. In Hutton's 'Theory of the Earth,' the outlines of which were published in 1788, the following operations are clearly recognised:—The degradation of the earth's surface by aqueous and atmospheric agencies; the deposition of the *débris* beneath the waters of the ocean; the consolidation and metamorphosis of the sedimentary deposits by the internal heat and by the injection of molten mineral matter; the disturbance and upheaval of the oceanic deposits; and, lastly, the formation of rocks by the consolidation of molten material both at the surface and in the interior of the earth.

Hutton regarded these operations as efficient causes ordained for the purpose of producing an earth adapted to sustain animal and vegetable life. His writings are saturated with the teleological philosophy of the age to which they belong, and some of his arguments strike us, therefore, as strange and inconclusive; moreover, the imperfect state of the sciences of chemistry and physics occasionally led him into serious error. Notwithstanding these imperfections, we are compelled to admit, when viewing his work in the light of modern knowledge, that we can find the traces, and sometimes far more than the traces, of those broad general theories relating to dynamical geology which are current at the present day.

If Hutton had contented himself with proving the reality of the agencies to which reference has been made, it is probable that his views would have been generally accepted. But he went much further than this, and boldly maintained that one or other of these agencies, or several combined, would account for all the phenomena with which the geologist has to deal. It was this that gave rise to the controversial fire which blazed up with such fury during the early years of this century, and whose dying embers have not yet been extinguished.

The views of Hutton were in strong contrast to those of Werner, the celebrated professor of mineralogy at Freiberg, to whom science owes a debt of gratitude as great as that due to the Scottish physician. The value of a man's work must not simply be judged by the truth of the theory which he holds. I consider that the Wernerian theory—by which I understand a reference to the early stages of planetary evolution for the purpose of explaining certain geological facts—has been on the wane from the time it was propounded down to the present day; but I claim to be second to none in my admiration for the knowledge, genius, and enthusiasm of the illustrious Saxon professor. The uniformitarian doctrines of Hutton gave a very decided character to the theoretical views of British geologists during the middle of the century, in consequence of the eloquent support of

Lyell; but of late there has been a tendency to hark back to a modified form of Wernerism. This tendency can, I think, be largely traced to the recognition of evolution as a factor in biology and physical astronomy. The discoveries in these sciences may necessitate a modification of the views held by some of the extreme advocates of uniformitarianism. This admission, however, by no means carries with it the conclusion that the methods based on the doctrine of uniformitarianism must be discarded. If I read the history of geology aright, every important advance in the theoretical interpretation of observed facts relating to physical geology has been made by the application of these methods. It does not, of course, follow that the progress in the future will be exactly along the same lines as that in the past; but, if I am right in the opinion I have expressed, it is a strong reason for adhering to the old methods until they have been proved to be inapplicable to at least some of the facts with which the physical geologist has to deal. Let us consider for a moment whether the recognition of evolution as a factor in biology and physical astronomy gives an *à priori* probability to some form of Wernerism.

The period of time represented by our fossiliferous records is perhaps equivalent to that occupied by the evolution of the vertebrata, but all the great subdivisions of the invertebrata were living in the Cambrian period, and must have been differentiated in still earlier times. Is it not probable, therefore, that the fossiliferous records at present known represent a period insignificant in comparison with that during which life has existed upon the earth? Again, is it not probable that the period during which life has existed is a still smaller fraction of that which has elapsed since the formation of the primitive crust? And if so, what *à priori* reason have we for believing that the rocks accessible to observation contain the records of the early stages of the planet's history? But the advocates of the diluted forms of Wernerism which find expression in geological writings at the present day almost invariably refer to recent speculations in cosmical physics. The views of astronomers have always had a powerful influence on those of geologists. Hutton wrote at a time when the astronomical world had been profoundly affected by Lagrange's discovery, in 1776, of the periodicity of the secular changes in the forms of the planetary orbits. The doubts as to the stability of the solar system which the recognition of these changes had inspired were thus removed, and astronomers could then see in the physical system of the universe 'no vestige of a beginning—no prospect of an end.' Now it is otherwise. Tidal friction and the dissipation of energy by the earth and by the sun are each referred to as fixing a limit to the existing conditions. I have not the knowledge necessary to enable me to discuss these questions, and I will therefore admit, for the sake of argument, that the phenomena referred to indicate the lines along which the physical evolution of our planet has taken place; but does it follow that geologists should desert a working hypothesis which has led to brilliant results in the past for one which has been tried again and again and always found wanting?

If there were absolute unanimity amongst mathematical physicists, it might be necessary for us to reconsider our position. This, however, is not the case. After referring to the argument from tidal friction, Professor Darwin, in his address to the Mathematical and Physical Section for 1886, says:—'On the whole, then, I can neither feel the cogency of the argument from tidal friction itself, nor, accepting it, can I place any reliance on the limits which it assigns to geological history.' In reviewing the argument from the secular cooling of the earth, he points out that the possibility of the generation of heat in the interior by tidal friction has been ignored, and that the thermal data on which the calculations are based are not sufficiently complete to remove all reasonable doubt. He regards the case depending on the secular cooling of the sun as the strongest; but it is evident that, in view of undreamt-of possibilities, he would not allow it to have much weight in the face of adverse geological evidence. In conclusion he says:—'Although speculations as to the future course of science are usually of little avail, yet it seems as likely that meteorology and geology will pass the word of command to cosmical physics as the converse. At present our knowledge of a definite limit to geological time has so little precision that we should do wrong to summarily reject any theories which appear to demand longer periods of time than those which now

appear allowable. In each branch of science hypothesis forms the nucleus for the aggregation of observation, and as long as facts are assimilated and co-ordinated we ought to follow our theory.' Now, my point is that the uniformitarian hypothesis, as applied to the rocks we can examine, has assimilated and co-ordinated so many facts in the past, and is assimilating and co-ordinating so many new discoveries, that we should continue to follow it, rather than plunge into the trackless waste of cosmogonical speculation in pursuit of what may after all prove to be a will-o'-the-wisp.

As an additional illustration of the want of agreement amongst mathematical physicists on questions relating to the earth, I may refer to certain papers by Mr. Chree.[1] This author maintains that the modern theory of elasticity points to the conclusion that if a spherical globe, composed of a nearly incompressible elastic solid of the size of the earth, were set rotating as the earth is rotating, it would take the form which the earth actually possesses. How is the question of the fixity of the earth's axis affected by Mr. Chree's researches, and by the recent observations which prove a simultaneous change of latitude, in opposite directions, in Europe and at Honolulu? If geological facts point to a shifting of the position of the axis, is there any dynamical reason why they should not receive due consideration? Geologists want as much freedom as possible. We do not object to any limitations which are necessary in the interest of science, and we cordially welcome, and as a matter of fact are largely dependent upon, assistance from other departments of knowledge; but those who would help us should bear in mind that the problems we have still to solve are extremely difficult and complex, so that if certain avenues of thought are closed on insufficient grounds by arguments of the validity of which we are unable to judge, but which we are naturally disposed to take on trust, the difficulties of our task may be greatly augmented and the progress of science seriously retarded. So far as I can judge, there is no *à priori* reason why we should believe that any of the rocks we now see were formed during the earlier stages of planetary evolution. We are free to examine them in our own way, and to draw on the bank of time to any extent that may seem necessary.

For some years past the greater part of my time has been devoted to a study of the composition and structure of rocks, and it has occurred to me that I might, on the present occasion, give expression to my views on the question as to whether the present position of petrographical science necessitates any important modification in the theoretical views introduced by the uniformitarian geologists. Must we supplement the ideas of Hutton and Lyell by any reference to primordial conditions when we endeavour to realise the manner in which the rocks we can see and handle were produced? The question I propose to consider is not whether some of these rocks *may* have been formed under physical conditions different from those which now exist—life is too short to make a discussion of geological possibilities a profitable pursuit—but whether the present state of petrographical science renders uniformitarianism untenable as a working hypothesis; and, if so, to what extent. There is nothing original in what I am about to lay before you. All that I propose to do is to select from the numerous facts and more or less conflicting views bearing on the question I have stated a few of those which appear to me to be of considerable importance.

The sedimentary rocks contain the history of life upon the earth, and on this account, as well as on account of their extensive development at the surface, they have necessarily received an amount of attention which is out of all proportion to their importance as constituent portions of the planet. They are, after all, only skin deep. If they were totally removed from our globe its importance as a member of the solar system would not be appreciably diminished. The general laws governing the formation and deposition of these sediments have been fairly well

[1] C. Chree, 'On Some Applications of Physics and Mathematics to Geology,' *Phil. Mag.*, vol. xxxii. (1891), pp. 233, 342.

understood for a long time. Hutton, as we have already seen, clearly realised that the land is always wasting away, and that the materials are accumulating on the beds of rivers, lakes, and seas. The chemical effects of denudation are mainly seen in the breaking up of certain silicates and the separation of their constituents into those which are soluble and those which are insoluble under surface conditions. The mechanical effects are seen in the disintegration of rocks, and this may, under certain circumstances, take place without the decomposition of their component minerals.[1] Quartz and the aluminous silicates, which enter largely into the composition of shales and clays, are two of the most important insoluble constituents. It must be remembered, however, that felspars often possess considerable powers of resistance, and rocks which contain them may be broken up without complete or anything like complete decomposition of these minerals. Orthoclase, microcline, and oligoclase are the varieties which most successfully resist decomposition; and, as a natural consequence, occur most abundantly in sedimentary deposits. It is commonly stated that when felspars are attacked the general effect is to reduce them to a fine powder, composed of a hydrated silicate of alumina, and to remove the alkalies, lime, and a portion of the silica. But, as Dr. Sterry Hunt has so frequently urged, the removal of alkalies is imperfect, for they are almost invariably present in argillaceous deposits. Three, four, and even five per cent., consisting mainly of potash, may frequently be found. This alkali appears to be present in micaceous minerals, which are often produced, as very minute scales, during the decomposition of felspars. White mica, whether formed in this way or as a product of igneous or metamorphic action, possesses great powers of resistance to the ordinary surface agencies of decomposition, and so may be used over and over again in the making of sedimentary deposits. Brown mica is also frequently separated from granite and other rocks, and deposited as a constituent of sediments; but it is far more liable to decomposition than the common white varieties, and its geological life is, therefore, comparatively short.[2] Small crystals and grains of zircon, rutile, ilmenite, cyanite, and tourmaline are nearly indestructible, and occur as accessory constituents in the finer-grained sandstones.[3] Garnet and staurolite also possess considerable powers of resistance, and are not unfrequently present in the same deposits. If we except the last two minerals and a few others, such as epidote, the silicates containing lime, iron, and magnesia are, as a rule, decomposed by surface agencies and the bases removed in solution; augite, enstatite, hornblende, and lime-felspars are extremely rare as constituents of ordinary sediments.

The insoluble constituents resulting from the waste of land surfaces are deposited as gravel, sand, and mud; the soluble constituents become separated as solid bodies by evaporation of the water in inland seas and lagoons, by chemical action, and by organic life. They are deposited as carbonates, sulphates, chlorides, and sometimes, as in the case of iron and manganese, as oxides. The soluble silica may be deposited in the opaline condition by the action of sponges, radiolaria, and diatoms, or as sinter.

The question that we have now to consider is whether there is any marked difference between ancient and modern sediments. One of the oldest deposits in the British Isles is the Torridon sandstone of the north-west of Scotland. The recent discovery of *Olenellus* high up in the stratified rocks which unconformably overlie this deposit has placed its pre-Cambrian age beyond all doubt. Now this formation is mainly composed of quartz and felspar, at least in its upper part, and the latter mineral is both abundant and very slightly altered. One is naturally tempted, at first sight, to associate the freshness of the felspar with the great age of the rock—to assume either that the sand was formed at a time when the chemical agents of decomposition did not act with the same force as now, or that they had

[1] J. W. Judd, 'Deposits of the Nile Delta,' *Proc. Royal Soc.*, vol. xxxix. 1886, p. 213.

[2] 'Notes on the Probable Origin of some Slates,' by W. Maynard Hutchings, *Geol. Mag.*, 1890, p. 264.

[3] 'Ueber das Vorkommen mikroskopischer Zirkone und Titan-Mineralien,' von Dr. Hans Thürach, *Verhandl. d. phys.-medic. Gesellschaft zu Würzburg*, N.F. xviii. 'On Zircons and other Minerals contained in Sand,' Allan B. Dick, *Nature*, vol. xxxvi. (1887), p. 91. See also 'Mem. Geol. Survey,' *Geology of London*, vol. i. p. 523.

not been in operation for a sufficient length of time to eliminate the felspar. A pure quartzose sand is probably never formed by the direct denudation of a granitic or gneissose area. The coarser sediments thus produced contain in most, if not in all, cases a considerable amount of felspar. But felspar is more liable to decomposition by percolating waters when it occurs as a constituent of grit than when present in the parent rock. Silica may thus be liberated in a soluble form, and subsequently deposited on the grains of quartz so as to give rise to secondary crystalline faces, and kaolin may be produced as beautiful six-sided tablets in the interstices of the grit. When the grit is in its turn denuded the felspar is still further reduced in amount, and a purer quartz-sand is formed. As the coarser detrital material is used over and over again, thus measuring different periods of time like the sand in an hour-glass, the felspar and other decomposable minerals are gradually eliminated. The occurrence of a large amount of fresh felspar in the Torridon sandstone might, I say, at first sight be thought to be due to the great age of the rock. Any tendency to accept a view of this kind is, however, at once checked when attention is paid to the pebbles in the coarser conglomeratic beds of the same deposit. These consist largely of quartzite—a rock formed by the consolidation of as pure a quartz-sand as any known to exist in the later formations. We are therefore led to the conclusion that the special features of the Torridon sandstone are not a function of time, but of the local conditions under which the rock was produced.

A similar conclusion may be reached by considering other types of sediment. When the stratified rocks of the different geological periods represented in any limited area are compared with each other certain marked differences may be observed, but the different types formed in any one area at different times can often be parallelled with the different types formed in different areas at the same time, and also with those now forming beneath the waters of rivers, lakes, and seas. Deep sea, shallow water, littoral and terrestrial deposits can be recognised in the formations belonging to many geological periods, from the most ancient to the most recent; and there is no evidence that any of our sedimentary rocks carry us back to a time when the physical conditions of the planet were materially different from those which now exist. After reviewing all the evidence at my disposal, I must, however, admit that the coarser as well as the finer deposits of the earlier periods appear to be more complex in composition than those of the later. The grits of the Palæozoic formations, taken as a whole, contain more felspar than the sandstones of the Mesozoic and Tertiary formations, and the slates and shales of the former contain more alkalies than the clays of the latter. This statement will hold good for the British Isles, even when allowance is made for the enormous amount of volcanic material amongst the older rocks—a phenomenon which I hold to be of purely local significance—but I strongly suspect that it will not be found to apply universally. In any case, it is not of much importance from our present point of view. All geologists will admit that denudation and deposition were taking place in pre-Cambrian times, under chemical and physical conditions very similar to, if not identical with, those of the present day.

There is, however, one general consideration of more serious import. Additions to the total amount of detrital material are now being made by the decomposition of igneous rocks, and there is no doubt that this has been going on during the whole period of time represented by our stratified deposits. It follows, therefore, as a necessary consequence that strict uniformitarianism is untenable, unless we suppose that igneous magmas are formed by the melting of sediments.

So far we have been dealing with the characters of sedimentary rocks as seen in hand-specimens rather than with those which depend on their distribution over large areas. Thanks to Delesse[1] and the officers of the 'Challenger' Expedition,[2] an attempt has now been made to construct maps on which the distribution of the sediments in course of formation at the present time is laid down. It is impossible to exaggerate the importance of such maps from a geological point of view, for on the facts which they express rests the correct interpretation of our stratigraphical

[1] *Lithologie du Fond des Mers.* Paris, 1871.
[2] *Report on Deep-sea Deposits,* 1891.

records. Imperfect as is our knowledge of the sea-beds of former geological periods, it is in many respects more complete than that of the sea-beds of the present day. The former we can often examine at our leisure, and follow from point to point in innumerable exposures; the latter are known only from a few soundings, often taken at great distances apart.[1] An examination of such imperfect maps as we have raises many questions of great interest and importance, to one of which I wish to direct special attention—not because it is new, but because it is often overlooked. The boundary lines separating the distinct types of deposit on these maps are not, of course, chronological lines. They do not separate sediments produced at different times, but different sediments simultaneously forming in different places. Now, the lines on our geological maps are usually drawn by tracing the boundary between two distinct lithological types, and, as a natural consequence, such lines will not always be chronological lines. It is only when the existing outcrop runs parallel with the margin of the original area of deposit that this is the fact. Consider the case of a subsiding area—or, to avoid theory, let us say an area in which the water-level rises relatively to the land—and, for the sake of illustration, let us suppose that the boundary separating the districts over which sand and mud are accumulating remains parallel to the old coast-line during the period of deposition. This line will follow the retreating coast, so that if, after the consolidation, emergence, and denudation of the deposits, the outcrop happens to be oblique to the old shore, then the line on the geological map separating clay and sand will not be of chronological value. That portion of it which lies nearer to the position of the vanished land will represent a later period than that which lies further away. If such organisms as ammonites leave their remains in the different deposits, and thus define different chronological horizons with approximate accuracy, the imperfection of the lithological boundary as a chronological horizon will become manifest. It is not that the geological map is wrong. Such maps have necessarily to be constructed with reference to economic considerations, and from this point of view the lithological boundaries are of paramount importance. They are, moreover, in many cases the only boundaries that can be actually traced.[2] The geological millennium will be near at hand when we can construct maps which shall represent the distribution of the different varieties of sediment for each of the different geological periods. All we can say at present is that increase of knowledge in this direction tends greatly to strengthen the uniformitarian hypothesis. We can see, for example, that during Triassic times marine conditions prevailed over a large part of what is now the great mountain-belt of the Euro-Asiatic continent, whilst littoral and terrestrial conditions existed in the north of Europe; and we can catch glimpses of the onward sweep of the sedimentary zones during the great Cretaceous transgression, culminating in the widespread deep-sea[3] conditions under which the Chalk was deposited.

We turn now to the igneous rocks. It is no part of my purpose to treat in detail of the growth of knowledge from an historical point of view and to attempt to allot to each observer the credit due to him; but there is one name that I desire to mention in this connection, because it is that of a man who clearly proved the essential identity of ancient and modern volcanic rocks by the application of precise petrographical methods at a time when there was a very general belief that the Tertiary and pre-Tertiary rocks were radically distinct. I need hardly say that I refer to Mr. Samuel Allport.[4] He wrote at a time when ob-

[1] Suess, *Das Antlitz der Erde*, Bd. II., s. 267.

[2] See S. S. Buckman, 'On the Cotteswold, Midford, and Yeovil Sands,' *Quart. Journ. Geol. Soc.*, vol. xlv. (1889), p. 440; and the same author, 'On the So-called Upper Lias Clay of Down Cliffs,' *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 518. Also J. Starkie Gardner, 'On the Relative Ages of the American and the English Cretaceous and Eocene Series,' *Geol. Mag.*, 1884, p. 492.

[3] Theodor Fuchs, 'Welche Ablagerungen haben wir als Tiefseebildungen zu betrachten?' *Neues Jahrbuch f. Miner.*, &c., Beilage, Band II., p. 487.

[4] 'Tertiary and Palæozoic Trap-rocks,' *Geol. Mag.*, 1873, p. 196; 'British Carboniferous Dolerites,' *Quart. Journ. Geol. Soc.*, vol. xxx. (1874), p. 529; 'Ancient Devitrified Pitchstones,' &c., *Quart. Journ. Geol. Soc.*, vol. xxxiii. (1877), p. 449.

servers in this country had to prepare their own sections, and those who, like myself, have had the privilege of examining many of his slides scarcely know which to admire most—the skill and patience of which they are the evidence, or the conciseness and accuracy of his petrographical descriptions. His papers do not occupy a large number of pages, but they are based on an amount of observation which is truly surprising. The general conclusions at which he arrived as to the essential identity of ancient and modern igneous rocks are expressed with the utmost confidence, and one feels, after going over his material, that this confidence was thoroughly justified. It is curious now to note that the one British champion of the distinctness of the Tertiary and pre-Tertiary rocks pointed to the difference between the Antrim and Limerick traps. These traps differ in exactly the same way as do the corresponding Tertiary and pre-Tertiary continental rocks, with this important difference. On the Continent the ophitic structure is characteristic of the pre-Tertiary rocks, whereas in the north of Ireland it is a marked feature of those of Tertiary age. We see, therefore, that the arguments for the distinctness of the two sets of rocks derived from the two areas, based in both cases on perfectly accurate observations, neutralise each other, and the case hopelessly breaks down as regards the basalts and dolerites.

In this country it is now generally recognised that, when allowance is made for alterations which are necessarily more marked in the earlier than in the later rocks, there is no important difference either in structure or composition between the rhyolites, andesites, and basalts of the Palæozoic and Tertiary periods. But identity of structure and composition may in this case be taken to imply identity as to the physical conditions under which the rocks were produced. We are thus led to picture in our minds long lines of volcanoes fringing the borders of Palæozoic continents and rising as islands in the Palæozoic seas. Then, as now, there issued from the craters of these volcanoes enormous masses of fragmental material, a large portion of which was blown to dust by the explosive escape of steam and other gases from the midst of molten rock; and then, as now, there issued from fissures on their flanks vast masses of lava which consolidated as rhyolite, andesite, and basalt. We may sum up the case as regards the volcanic rocks by saying that, so long as observations are confined to a limited area, doubts may arise as to the truth of the uniformitarian view, but these doubts gradually fade away as the area of observation is extended. There are still some outstanding difficulties, such as the apparent absence of leucite lavas amongst the Palæozoic formations; but as many similar difficulties have been overcome in the past, it is improbable that those which remain are of a very formidable character.

So far we have been referring to rocks formed at the surface of the earth under conditions similar to those now in operation. But there are others, such as granite, gneiss, and mica-schist, which are obviously unlike any of the products of surface agencies. If these rocks are forming now, it must be beneath the surface. This point was clearly realised by Hutton. Granite was proved by him to be an igneous rock of subterranean origin. His conclusions as to the formation of the schists are expressed in a passage so remarkable when viewed in connection with what I regard as the tendency of modern research that I make no apology for quoting it at length. 'If, in examining our land, we shall find a mass of matter which had been evidently formed originally in the ordinary manner of stratification, but which is now extremely distorted in its structure, and displaced in its position—which is also extremely consolidated in its mass, and variously changed in its composition—which therefore has the marks of its original or marine composition extremely obliterated, and many subsequent veins of melted mineral matter interjected; we should then have reason to suppose that here were masses of matter which, though not different in their origin from those that are gradually deposited at the bottom of the ocean, have been more acted upon by subterranean heat and the expanding power, that is to say, have been changed in a greater degree by the operations of the mineral region. If this conclusion shall be thought reasonable, then here is an explanation of all the peculiar appearances of the Alpine schistus masses of our land, those parts which have been erroneously

considered as primitive in the constitution of the earth.'[1] Surely it is not claiming too much for our author to say that we have there, sketched in broad outline, the theories of thermal and dynamic metamorphism which are attracting so much attention at the present day.

The hypogene origin of the normal plutonic rocks and their formation at different periods, even as late as the Tertiary, are facts which are now so generally recognised that we may leave these rocks without further comment and pass on to the consideration of the crystalline schists.

Everyone knows that the statement, 'He who runs may read,' is untrue when the stratigraphical interpretation of an intensely folded and faulted district is concerned. The complexity produced by the earth-movements in such regions can only be unravelled by detailed work after definite palæontological and lithological horizons have been established. But if the statement be untrue when applied to districts composed of ordinary stratified rocks, still less can it be true of regions of crystalline schist where the movements have often been much more intense; where the original characters of the rocks have been profoundly modified; and where all distinct traces of fossils have in most cases been obliterated. If detailed work like that of Professor Lapworth at Dobb's Linn was required to solve the stratigraphical difficulties of the Southern Uplands, is it not probable that even more detailed work will be required to solve the structural problems of such a district as the Highlands of Scotland, where the earth-stresses, though somewhat similar, have operated with greater intensity, and where the injection of molten mineral matter has taken place more than once both on a large and on a small scale? With these few general remarks by way of introduction, I will now call attention to what appear to me to be the most promising lines of investigation in this department of geology.

The crystalline schists certainly do not form a natural group. Some are undoubtedly plutonic igneous rocks showing original fluxion; others are igneous rocks which have been deformed by earth-stresses subsequent to consolidation; others, again, are sedimentary rocks metamorphosed by dynamic and thermal agencies, and more or less injected with 'molten mineral matter'; and lastly, some cannot be classified with certainty under any of these heads. So much being granted, it is obvious that we must deal with this petrographical complex by separating from it those rocks about the origin of which there can be no reasonable doubt. Until this separation has been effected, it is quite impossible to discuss with profit the question as to whether any portions of the primitive crust remain. In order to carry out this work it is necessary to establish some criterion by which the rocks of igneous may be separated from those of sedimentary origin. Such a criterion may, I think, be found, at any rate in many cases, by combining chemical with field evidence.[2] If associated rocks possess the composition of grits, sandstones, shales, and limestones, and contain also traces of stratification, it seems perfectly justifiable to conclude that they must have been originally formed by processes of denudation and deposition. That we have such rocks in the Alps and in the Central Highlands of Scotland, to mention only two localities, will be admitted by all who are familiar with those regions. Again, if the associated rocks possess the composition of igneous products, it seems equally reasonable to conclude that they are of igneous origin. Such a series we find in the north-west of Scotland, in the Malvern Hills, and at the Lizard. In applying the test of chemical composition it is very necessary to remember that it must be based, not on a comparison of individual specimens, but of groups of specimens. A granite and an arkose, a granitic gneiss and a gneiss formed by the metamorphosis of a grit, may agree in chemical and even in mineralogical composition. The chemical test would therefore utterly fail if employed for the purpose of discriminating between these rocks. But when we introduce the principle of paragenesis it enables us in many cases to distinguish between them. The granitic gneiss will be associated with rocks having the composition of diorites, gabbros, and peridotites; the sedimentary gneiss, with rocks

[1] *Theory of the Earth*, vol. i. p. 375.

[2] H. Rosenbusch, 'Zur Auffassung der chemischen Natur des Grundgebirges,' *Min. und petro. Mitth.*, xii. (1891), p. 49.

answering to sandstones, shales, and limestones. Apply this test to the gneisses of Scotland, and I believe it will be found in many cases to furnish a solution of the problem. Caution, however, is necessary; for crystal-building and the formation of segregation veins and patches in the sedimentary schists clearly prove that a migration of constituents takes place under certain circumstances.

Recent work on the gneisses and schists of igneous composition has shown that the parallel structure, by no means invariably present, is sometimes the result of fluxion during the final stages of consolidation, and sometimes due to the plastic deformation of solid rocks. When compared with masses of ordinary plutonic rock, the principal points of difference, apart from those due to secondary dynamic causes, depend on what may be called their extreme petrographical differentiation. Indications of differentiation may, however, be seen in the contemporaneous veins and basic patches so common in ordinary irruptive bosses, but they are never so marked as in gneissic regions, like those of the north-west of Scotland, where specimens answering in composition to granites, diorites, and even peridotites may be collected repeatedly in very limited areas. The nearest approach to the conditions of gneissose regions is to be found in connected masses of diverse plutonic rocks, such as those which are sometimes found on the borders of great granitic intrusions.

The tectonic relations of those gneisses which resemble igneous rocks in composition fully bear out the plutonic theory as to their origin. Thus, the intrusive character of granitic gneiss in a portion of the Himalayas has been demonstrated by General McMahon.[1] The protogine of Mont Blanc has been investigated by M. Lévy [2] with the same result. Most significant of all are the discoveries in the vast Archæan region of Canada. Professor Lawson [3] has shown that immense areas of the so-called Laurentian gneiss in the district north-west of Lake Superior are intrusive in the surrounding rocks, and therefore newer, not older, than these. Professor Adams [4] has quite recently established a similar fact as regards the anorthosite rocks—the so-called Norian—of the Saguenay River and other districts lying near the eastern margin of the 'Canadian shield.' Now that the intrusive character of so many gneisses is being recognised, one wonders where the tide of discovery will stop. How long will it be before the existence of gneisses of Tertiary age will be generally admitted? At any rate, the discoveries of recent years have compelled the followers of Wernerian methods to evacuate large slices of territory.

Turning now to the gneisses and schists which resemble sedimentary rocks in composition, we note that the parallel structure may be due to original stratification, to subsequent deformation, or to both of these agencies combined. It must also be remembered that they have often been injected with igneous material, as Hutton pointed out. Where this has followed parallel planes of weakness, we have a banding due to alternations of igneous and sedimentary material. This injection *lit par lit* has been shown by M. Lévy to be a potent cause in the formation of certain banded gneisses.

Will the various agencies to which reference has been made explain all the phenomena of the crystalline schists and gneisses? I do not think that the present state of our knowledge justifies us in answering this question in the affirmative. Those who are working on these rocks frequently have brought under their notice specimens about the origin of which they are not able to speak with any degree of confidence. Sometimes a flood of light is suddenly thrown on a group of doubtful rocks by the recognition of a character which gives unmistakable indications of their mode of origin. Thus, some of the fine-grained quartz-felspathic rocks associated with the crystalline schists of the Central Highlands are proved to have

[1] 'The Geology of Dalhousie,' *Records of Geol. Survey of India*, vol. xv. part 1 (1882), p. 34. See also vol. xvi. part 3 (1883), p. 129.

[2] 'Les Roches Crystallines et Eruptives des Environs du Mont-Blanc,' *Bull. des Services de la Carte Géologique de la France*, No. 9 (1890).

[3] 'On the Geology of the Rainy Lake Region,' *Annual Report Geol. Survey of Canada* for 1887.

[4] 'Ueber das Norian oder Ober-Laurentian von Canada,' *Neues Jahrbuch f. Mineralogie*, &c., Beilage, Band viii. p. 419.

been originally sands like those of Hampstead Heath by the presence in them of narrow bands rich in zircon, rutile, and the other heavy minerals which are so constantly present in the finer-grained arenaceous deposits of all ages. Such pleasant surprises as the recognition of a character like this increase our confidence in the theory which endeavours to explain the past by reference to the present, and refuses to admit the necessity of believing in the existence of rocks formed under physical conditions different from those which now prevail simply because there are some whose origin is still involved in mystery.

A crystalline schist has been aptly compared to a palimpsest. Historical records of priceless value have often been obscured by the superposition of later writings; so it is with the records of the rocks. In the case of the schists the original characters have been so modified by folding, faulting, deformation, crystallisation, and segregation that they have often become unrecognisable. But when the associated rocks have the composition of sediments we need have no hesitation in attributing the banded structure in some way to stratification, provided we clearly recognise that the order of succession and the relative thicknesses of the original beds cannot be ascertained by applying the principles which are valid in comparatively undisturbed regions.

In studying the crystalline schists nothing, perhaps, strikes one more forcibly than the evidence of crystal-building in solid rocks. Chiastolite, staurolite, andalusite, garnet, albite, cordierite, micas of various kinds, and many other minerals have clearly been developed without anything like fusion having taken place. Traces of previous movements may not unfrequently be found in the arrangement of the inclusions, while the minerals themselves show no signs of deformation. Facts of this kind, when they occur, clearly indicate that the crystallisation was subsequent to the mechanical action. Nevertheless, it is probable that both phenomena were closely related, though not in all cases as cause and effect. The intrusion of large masses of plutonic rock often marks the close of a period of folding. This is well illustrated by the relation of granite to the surrounding rocks in the Lake District, the Southern Uplands of Scotland, and the west of England. Those of the two first-mentioned localities are post-Silurian and pre-Carboniferous, those of the last-mentioned locality are post-Carboniferous and pre-Permian; one set followed the Caledonian[1] folding, the other set followed the Hercynian folding. That the intrusion of these granites was subsequent to the main movements which produced the folding and cleavage is proved by the fact that the mechanical structures may often be recognised in the crystalline contact-rocks, although the individual minerals have not been strained or broken. In many other respects the rocks produced by so-called contact-metamorphism resemble those found in certain areas of crystalline schist. Many of the most characteristic minerals are common to the two sets of rocks, and so also are many structures. The cipolins and associated rocks of schistose regions have many points of resemblance to the crystalline limestones and 'kalksilicathornfels' produced by contact-metamorphism.[2]

These facts make it highly probable that, by studying the metamorphic action surrounding plutonic masses, we may gain an insight into the causes which have produced the crystalline schists of sedimentary origin; just as, by studying the intrusive masses themselves and noting the tendency to petrographical differentiation, especially at the margins, we may gain an insight into the causes which have produced the gneisses of igneous origin.[3] In the districts to which reference has been made the igneous material came from below into a region where the rocks had been rendered tolerably rigid. Differential movement was not taking place in these rocks when the intrusion occurred. Consider what must happen if the folding stresses operate on the zone separating the sedimentary rocks from the

[1] This term is employed in the sense in which it is used by Suess and Bertrand.

[2] H. Rosenbusch, 'Zur Auffassung des Grundgebirges,' *Neues Jahr. f. Miner.*, Bd. II. 1889, p. 8.

[3] G. Barrow, 'On an Intrusion of Muscovite-biotite-gneiss in the South-eastern Highlands of Scotland, &c.,' *Quart. Journ. Geol. Soc.*, vol. xlix. (1893), p. 330.

underlying source of igneous material. Intrusion must then take place during interstitial movement, fluxion structures will be produced in the more or less differentiated igneous magmas, the sediments will be injected and impregnated with igneous material, and thermo-metamorphism will be produced on a regional scale. The origin of gneisses and schists, in my opinion, is to be sought for in a combination of the thermal and dynamic agencies which may be reasonably supposed to operate in the deeper zones of the earth's crust. If this view be correct, it is not improbable that we may have crystalline schists and gneisses of post-Silurian age in the north-west of Europe formed during the Caledonian folding, others in Central Europe of post-Devonian age due to the Hercynian folding, and yet others in Southern Europe of post-Cretaceous age produced in connection with the Alpine folding.[1] But if the existence of such schists should ultimately be established it will still probably remain true that rocks of this character are in most cases of pre-Cambrian age. May not this be due to the fact, suggested by a consideration of the biological evidence, that the time covered by our fossiliferous records is but a small fraction of that during which the present physical conditions have remained practically constant?

The good old British ship 'Uniformity,' built by Hutton and refitted by Lyell, has won so many glorious victories in the past, and appears still to be in such excellent fighting trim, that I see no reason why she should haul down her colours either to 'Catastrophe' or 'Evolution.' Instead, therefore, of acceding to the request to 'hurry up' we make a demand for more time. The early stages of the planet's history may form a legitimate subject for the speculations of mathematical physicists, but there seems good reason to believe that they lie beyond the ken of those geologists who concern themselves only with the records of the rocks.

In this address I have ventured to express my views on certain disputed theoretical questions, and I must not conclude without a word of caution. The fact is, I attach very little importance to my own opinions, at least on doubtful questions connected with the origin of the crystalline schists; but, as you have done me the honour to accept me as your President, I thought you might like to know my present attitude of mind towards some of the unsolved problems of geology. There is still room for legitimate difference of opinion on many of the subjects to which I have referred. Meanwhile, we cannot do better than remember the words with which one of our great living masters recently concluded an article on a controversial subject: 'Let us continue our work and remain friends.'

[1] Some geologists maintain that this is the case, others deny it. See H. Reusch, 'Die fossilienführenden krystallinischen Schiefer von Bergen in Norwegen,' Leipzig, 1883; J. Lehmann, 'Ueber die Entstehung der altkrystallinischen Schiefergesteine, mit besonderer Bezugnahme auf des sächsische Granulitgebirge, Erzgebirge, Fichtelgebirge, und bairisch-böhmische Grenzgebirge,' Bonn, 1884; T. G. Bonney, several papers on the Alps, and especially 'On the Crystalline Schists and their Relation to the Mesozoic Rocks of the Lepontine Alps,' *Quart. Journ. Geol. Soc.*, vol. xlvi. (1890), p. 188; A. Heim, contribution to the discussion on the last paper; C. W. Gümbel, 'Geognostische Beschreibung des K. Bayern' and 'Grundzüge der Geologie,' Kassel, 1888–1892.

Although it is convenient to speak of the three types of folding which have so largely influenced the structure of the European continent as if each belonged to a definite period, it is important to remember that this is not strictly true. The movements were prolonged; they probably crept slowly over the surface of the lithosphere, as did the zones of sedimentation, so that those of the same type are not in all places strictly contemporaneous.

The following Papers and Reports were read:—

1. *Notes on the Water-bearing Capacity of the New Red Sandstone of Nottingham. By* Professor Edward Hull, *LL.D., F.R.S., F.G.S.*

About half a century ago, before the problems of sanitation were generally understood, the town of Nottingham was placed in a most unfavourable position as

regards drainage and water-supply. As regards the former the drainage of the houses for the most part was run off into cesspools sunk in the sandstone rock on which the town is built; and as regards the latter the water-supply was drawn from wells sunk through the same formation down to the water-level, so that often the cesspools and wells were in proximity to each other. The result of such a state of affairs may easily be surmised. However excellent as a filter may be the sandstone rock, it must assuredly become clogged with fæcal matter when filtration of water is carried on for an indefinite period, subject to such contamination as is here referred to, and in course of time the water from the wells becomes unfit for drinking and household purposes.

Now all this is changed: the cesspools have been closed or filled up, and the water-supply is drawn from large and deep wells far removed from possibility of contamination.

Few towns in central England are more favourably situated for purposes of water-supply than Nottingham. Built on a foundation of New Red Sandstone and conglomerate, which rises at the Castle in a precipitous cliff above the valley of the Trent, the formation on which the city stands in its prolongation northwards is a source of water-supply of the highest excellence, and yields several millions of gallons per day of pure water from three or four wells situated within a few miles of the city.

The conditions which render this formation so well adapted for water-supply may be briefly explained. The succession and character of the strata all combine towards this end.

In descending order the succession is as follows:—

TRIAS	*Keuper Marls* . . .	Red and variegated marl, shaly and gypseous (slightly permeable).
	Waterstones and Lower Keuper Sandstone	Laminated micaceous sandstones alternating with marls and shales.
	Bunter Sandstone . .	Soft yellow and reddish sandstone and conglomerate (permeable).
PERMIAN	*Red Calcareous Marls* .	These are the strata separating the Upper and Lower limestones of the Worksop district to the north (impervious).
	Lower Magnesian Limestone	Sandy magnesian limestones.

From the above succession it will be seen that the permeable beds of the Bunter Sandstone, about 200 feet in thickness, are underlain by impervious marls of the Permian series, which thus form a water-tight floor, effectually preventing the water which percolates downwards from the surface to escape into the magnesian limestone; and, as the beds dip eastwards at a small angle from the western margin of the formation, an underground reservoir is thus formed with a naturally permanent level corresponding to that of the springs which break out at the junction of the sandstone with the marl along the western outcrop.

The proportion of the rainfall, taken at an average of 30 inches, which sinks down into the Bunter Sandstone north of Nottingham must be very large owing to the absence of drift deposits and the sandy character of the ground. As there is no surface drainage the percolation cannot be less than about 20 inches per annum, giving a supply of about 1,000,000 gallons to every 3 square miles. Taking the area of the formation between Nottingham and Worksop at 120 square miles, the amount of water which annually percolates into the rock and becomes a reservoir of supply may be estimated at about 40,000,000 gallons per day.

This large quantity of water tends to flow eastwards, following the dip of the beds; and that it has permanently saturated the Bunter Sandstone under an extensive area occupied by the overlying formations is proved by the result of the boring at Scarle, near Lincoln, which, commencing in the Lower Lias, passed down through the Keuper marls into the Bunter, when the water came up with force and flowed over the surface.[1] This boring is at a minimum distance of 20 miles from the

[1] Two feeders of water were struck—one at a depth of 917 feet in the Lower Keuper Sandstone, and the other at 1,250 feet in the Bunter Sandstone.

margin of the Bunter Sandstone. From these considerations it may be inferred that Nottingham is most favourably situated as regards its water-supply for a long period to come; a circumstance of great importance at a time when so many large manufacturing towns are looking forwards with anxiety to the future as regards this prime necessary of progress and prosperity.

Since the above was written I have been favoured by Mr. L. T. Godfrey Evans, the Borough Engineer, with information, of which the following is a summary:—

There are four pumping stations, of which one, the Park, Zion Hill, is not now in use. The others are:—

1. Basford or Bagthorpe, yielding 12,800,000 gallons per week.
2. Bestwood, yielding 11,800,000 „ „
3. Papplewick, yielding 12,190,000 „ „

In all 36,790,000 gallons per week, or 5,257,143 gallons per day.

The supply at Bestwood is decreasing, owing probably to mining operations in the neighbourhood. The yield at the Park Station is about $5\frac{1}{2}$ millions of gallons per week. The water is excellent.

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2. *On a Nottingham Sandstone containing Barium Sulphate as a Cementing Material. By* Professor Frank Clowes, *D.Sc.* (*See p.* 732.)

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3. *On the Discovery of a Concealed Ridge of pre-Carboniferous Rocks under the Trias of Netherseal, Leicestershire. By* Professor Edward Hull, *LL.D., F.R.S., F.G.S.*

It is now generally recognised that the Leicestershire and Warwickshire Coal-measures were deposited along the borders of a land surface of older Palæozoic rocks, of which the visible representatives occur at Charnwood Forest and Atherstone. The attenuated condition of the Lower Carboniferous beds at Calke Abbey on the north of the Leicestershire Coalfield and their entire absence below the Coal-measures of Warwickshire show that these older rocks remained unsubmerged till the commencement of the Upper Carboniferous period, when they were gradually overspread, as the land became depressed, by successive deposits of the Coal period. The general north-westerly trend of these old foundation rocks, both at Charnwood Forest and Atherstone, appears to indicate that this old land was composed of a succession of ridges and furrows running in N.W. and S.E. directions; but as the country is for the most part covered by Triassic strata the position of such ridges and hollows can only be determined by experiment. One of these ridges appears to have been in this manner determined at Netherseal Colliery in a boring put down for the purpose of determining the extension of 'the main coal.' Having been invited by Mr. G. J. Binns, F.G.S., the manager of the colliery, to give my opinion regarding the age of the beds passed through in the lower part of the boring, I visited the colliery and inspected the cores which were brought up and were arranged in their order of relative depth at the works. The following is an abstract of the strata passed through:—

Trias . .	*Bunter Sandstone*; light reddish-brown, pebbly sandstone; 262 feet.
Coal-measures	Grey and black shales and sandstones, with coal and ironstone; plants abundant; 514 feet.
Pre-Carboniferous	Reddish, purple and grey grit, sandstone and micaceous quartzite; 19 feet.

The interest attaches to the beds called 'pre-Carboniferous.' They consist of sandstones, grits, and quartzites, of purple and yellowish tints, occasionally shaly. They contrast strongly with the Coal-measures, not only in the absence of beds of coal, grey and black shale and ironstone, but also in the complete absence of plant remains with which the overlying Coal-measures are crowded; not one solitary

instance of any plant-form having been found amongst all the cores after careful examination. It became clear that the beds were not of Carboniferous age, yet it was very difficult to determine with certainty to what period they were to be referred. Such sandstones, grits, and quartzites might be found in several pre-Carboniferous formations, either the Old Red Sandstone, the Upper Silurian, Lower Silurian (Ordovician), or Cambrian. A reference to the Old Red Sandstone was considered out of the question, as this formation is not found anywhere in this part of England; nor did it seem probable that they were referable to the Upper or Lower Silurian period, though this is possible. On the other hand, we cannot forget that at no great distance to the south of the boring the Lower Cambrian beds form the floor of the Coal-measures, and, although the cores at Netherseal boring do not show a very strong resemblance to those of the Hartshill ridge, there is no good reason why they may not be referable to the same general period, and consist of beds not visible in that locality. For these reasons I am disposed with some hesitation to regard them as of Lower Cambrian age; a view in which I am supported by Professor Lapworth, who was kind enough to examine the specimens of the cores which I brought away with me from Netherseal Colliery. I will only add that no conclusion could be gathered regarding the question of unconformity of these beds with the overlying Coal-measures, as the dip of both series appeared to be very slight. A strong discordance could have been immediately detected.

Since the above was written No. 2 boring has entered these old rocks, and the specimens brought up confirm the conclusion arrived at from the results of boring No. 1. The rock entered at a depth of about 760 feet consists of reddish vitreous quartzite, slightly micaceous, and very similar to the Hartshill stone of Warwickshire.

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4. *On the Geology of the Coastland of Caria.* By JOHN L. MYRES.

The interior of Caria, so far as it has been explored, presents only thick bedded blue and grey limestones of Cretaceous age, lying almost horizontally, and forming great plateaus with steep sea-slopes, the natural drainage falling partly into deep gorges, partly into the frequent swallow-holes.

In the peninsula, however, which projects westward beyond Budrum (the ancient Halikarnassos) the occurrence of a volcanic series, both below and above the thick limestones, causes a complete change in the character of the country.

The 'fundamental' beds of this area are light-coloured crystalline quartzose and felspathic rocks, which are interbanded with one another, and present occasionally traces of foliation. The dips are almost universally to the east, and rise in some places to the vertical, but are not wholly pre-Cretaceous. The age of these beds is quite undetermined, but they may probably be correlated with the very similar beds in Patmos, and with those which underlie the thick limestones in the eastern half of the peninsula of Kavo Krio further south, and the white marble series which represents them in Naxos, Attica, and elsewhere.

These beds are traversed, as in Patmos and Naxos, by numerous necks and dykes of very various composition. Two or three types, however, may be distinguished, and appear to represent successive periods of volcanic action. In particular, a purple porphyritic rock which is especially common in the neighbourhood of Gumashli (ancient Myndos), on the west coast, occurs as the main constituent in an altered tuff, underlying the basal schists of the limestone series, in which several other common types are not represented.

The pre-Cretaceous volcanic outbreak was not yet over when the great subsidence began at the opening of the Limestone period; for the last deposits of débris on the flanks of the old land-mass have a distinctly subaqueous character, and are immediately succeeded by fine clays and schists at the base of the great limestones. The lower part of this series is in this region unusually full of thin sandy beds, and it contains also a number of bands of black chert in the parts east of Budrum. The higher beds, however, are cleaner, and conform to the more normal type represented in the neighbouring areas of Kavo Krio, Kos, and Kalymnos. One small outlier in the middle of the volcanic area has been wholly metamorphosed

into a coarsely crystalline and very clean white marble, strikingly like that of Naxos; and a large area east of Budrum shows signs of similar but less complete metamorphism. The basal sands and clays are in all cases much more altered than the limestones associated with them.

At the end of the Limestone period a prolonged elevation allowed of the erosion of the principal existing features of the Carian coastland; so that the Tertiary beds which cling about the slopes of the limestones and older rocks have all a littoral character, which is maintained in the eastern part of Kos; though in the central plain of that island deep-water limestones of some thickness occur. This series consists of a basal breccia of limestone and fragments of crystalline rocks, followed by sandstones and schistose clays, and then by thin-bedded cream-coloured clayey limestones of the normal type. All these are locally altered where they come in contact with rocks of the later volcanic series. In the absence of fossils these beds can only be roughly correlated with the very similar rocks in Rhodes and Crete to the south, and of Samos, Chios, and the mainland opposite to the north.

Above this normal series occurs a thick but very irregular accumulation of volcanic débris, which can be associated with a second series of necks and dykes in the old rocks. The limestone appears to have been largely denuded from the western half of the peninsula before the outbreak took place; but boulders of it occur in a very perplexing, mainly volcanic, breccia near Gumashli. A very marked local variety of this volcanic series on the coast between Gumashli and Geretsi supplied in classical and mediæval times an admirable peperino for building purposes, which is still occasionally worked. The latest beds found in this area are almost wholly composed of pumice, and may be referred to the very recent volcanic centres in Kos and Nisyros. They fill several small bays in the peninsulas of Budrum and Kavo Krio, are well developed on the shores of Porto Kalymno, and fringe the steep south-east shore of Kos, over against Nisyros, where they contain larger fragments, and are associated with limestone. They are almost always level; cliff breccias seldom occur more than twenty or thirty feet above the sea-level, and are probably of very recent date.

It may be noted in conclusion that the argentiferous galena, which was worked so largely in classical and mediæval times at Gumashli (the Turkish name means 'Silver Town'), is still found frequently, and of good quality, in the old rocks of the neighbourhood. Many good veins of pyrolusite have lately been reported in the same series near Gumashli and Kephaloucha, and a cobalt mineral, not yet assayed, is found in workable quantities at the latter place.

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5. *Report on the Fossil Phyllopoda of the Palæozoic Rocks.*

See Reports, p. 465.

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6. *On the Discovery of* Cephalaspis *in the Caithness Flags.* *By* Dr. R. H. Traquair, *F.R.S.*

The author described a new species of *Cephalaspis* (*C. magnifica*, Traq.), from Spittal Pavement Quarry, Caithness, resembling *C. Campbelltownensis*, Whiteaves, in having a pointed snout, but differing from it in having the cornua proportionately short and broad-based, instead of slender and curved; the cranial shield is ornamented externally by a very fine tuberculation, and the inner margins of the cornua are not denticulated. This is the first recorded occurrence of *Cephalaspis* in the Orcadian area of the Old Red Sandstone north of the Grampians, and the species is the largest known, the length of the cranial shield being no less than 8½ inches.

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7. *Report on the Eurypterid-bearing Deposits of the Pentland Hills.*

See Reports, p. 470.

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8. *On some Vertebrate Remains not hitherto recorded from the Rhætic Beds of Britain.* *By* MONTAGUE BROWNE, *F.G.S., F.Z.S.*

Plesiosaurus rostratus, Owen.[1]

In the autumn of 1890, when visiting Aust Cliff for a day, the writer found some interesting vertebrate remains in the celebrated Rhætic 'bone-bed' there. Amongst others was a large tooth which there was little difficulty in referring to the so-called *Termatosaurus albertii*, a description of which, with figures, was published by Plieninger[2] in 1844, and by Quenstedt[3] in 1858. This type of tooth has been queried subsequently, indeed, by Quenstedt himself,[4] as pertaining to a Plesiosaurus, but the species has never been determined. Since 1890 the Rhætics of Aust Cliff, of Westbury-on-Severn, and of the Spinney Hills, Leicester, have yielded to the writer teeth of the same character, and he has recognised similar specimens, either unreferred or attributed to *Termatosaurus albertii*, in the British, Bath, Bristol, Cardiff, Gloucester, and Leicester Museums, the Museum of Practical Geology, Jermyn Street, and some from the Rhætics of Stanton-on-the-Wolds, Nottinghamshire, collected by Mr. E. Wilson, F.G.S.

During a visit to the Geological Department at South Kensington the writer succeeded in referring them, with some certainty, to *Plesiosaurus rostratus*, and considered that, could some vertebræ of the same Plesiosaurian be found, this would furnish corroborative evidence. On a second and third visit to Aust, therefore (in 1891–92)—both of several weeks' duration—no pains were spared in searching for vertebræ, with the result that several specimens were procured: and since that time many have been acquired, by purchase and presentation, from the same beds, and others have been recognised as Rhætic specimens in the British, Bristol, and Gloucester Museums; whilst subsequent visits to the British Museum, and an examination of the whole of the vertebræ there definitely assigned to *Plesiosaurus rostratus*, have resulted in the conviction that the Rhætic Plesiosaurian vertebræ are specifically identical. It is noteworthy also that one of the specimens in the writer's possession—a cervical vertebra—might have been used for the figure given by Owen[5] on tab. x. fig. 1, and the description tallies well, especially on p. 23, where is stated the fact, patent on all the Rhætic specimens possessed or seen by the writer, that 'the fore surface of the centrum presents a slightly fibrous character, not so smooth as in some other species, nor so irregular as in the *Plesiosaurus rugosus*, for example;' and again, on pp. 24, 25, 'The sides of the neural spines of these vertebræ are roughened by irregular or granulate ridges, directed toward their summit, which is bent backward.' Another agrees *exactly* with No. 39849 British Museum specimen labelled *Eretmosaurus rugosus*, but which has been shown[6] to be a vertebra of *Plesiosaurus rostratus* from the Lias of Lyme Regis.

The specific determination of this Plesiosaurus (hitherto recognised only as Liassic) is a new record altogether for the Rhætic throughout the world, its vertebræ having hitherto been referred generically only, and its teeth having been recorded as *Termatosaurus albertii*, Plieninger, and *Plesiosaurus* sp. non det. The synonymy, therefore, will be as follows:—

[1] *A Monograph of the Fossil Reptilia of the Liassic Formations*, part iii. (Palæontographical Society, 1865), pp. 20–30, plates ix.–xiii. Note, however, that part of the description between pp. 26–30 refers to *Plesiosaurus conybearei* [-ri] (Sollas), as does the whole of the plate (skull), tab. xiii. (see R. Lydekker, *Catalogue of Fossil Reptilia and Amphibia*, British Museum, part ii. pp. 269, 270, and Woodward and Sherborn).

[2] *Beiträge zur Paläontologie Württemberg's* (1884), p. 123, tab. xii. figs. 93, 94.

[3] *Der Jura* (1858), p. 33, and atlas, tab. ii. figs. 4–8.

[4] *Handbuch der Petrefaktenkunde* (1885) p. 212, tab. xvi. figs. 7–10.

[5] See *note* above (*op. cit.*).

[6] *Catalogue of Fossil Reptilia and Amphibia*, British Museum, vol. ii. p. 273.

Plesiosaurus rostratus, Owen.

By Teeth.	By Vertebræ.
Termatosaurus albertii, Plieninger.	*Termatosaurus, Plesiosaurus?* Quenstedt.
Plesiosaurus sp. non det. of various authors.	Plesiosaurian vertebræ of various authors.

Termatosaurus crocodilinus, Quenstedt.

Teeth similar to those described and figured by Quenstedt[1] under the above name, and not hitherto recognised as such in Britain, have been procured by the writer from the Rhætics of Aust Cliff, Westbury-on-Severn, and the Spinney Hills, Leicester, and others have been recognised by him in the collections in the British, Bath, Bristol, Cardiff, Gloucester, and Leicester Museums, in the Museum of Practical Geology, Jermyn Street, and some collected by Mr. Wilson from Stanton-on-the-Wolds.

These recall the characters of an Ichthyosaurian tooth of the platyodont type, and, indeed, are recorded by Mr. Wilson[2] as *Ichthyosaurus platyodon*; yet a close comparison of the tooth with that of Ichthyosaurus, and with those of Rhætic Labyrinthodontia, leads to the conclusion that it is to the latter (sp. ind.) they must be assigned. In this connection the writer, having probably a larger amount of such material at his disposal than is elsewhere known, is convinced that teeth of various species of *Saurichthys*, Ag.,[3] and other authors will have to be divided between the Labyrinthodontia and various species of fishes, being, probably, called *Saurichthys* erroneously.

Ceratodus (? latissimus), Ag.

In 1890 the writer found a small bone, which, having somewhat the texture and appearance of a *Ceratodus* tooth, was labelled as probably pertaining to *Ceratodus;* but on the second visit, in 1891, more and larger pieces were found of the same nature, but which, having the appearance of plates of the ichthyic skull, were provisionally referred to *Ceratodus.* One was shown to Mr. A. Smith Woodward, F.G.S., F.Z.S., who concurred in this opinion, at the same time calling attention to a recent memoir upon the skull of a *Ceratodus* by F. Teller.[4] On comparison with the description and plates, it now appears that some of these bones are the median and other plates of the skull of *Ceratodus*; and although, no doubt, they have been collected before, and in one instance within the writer's knowledge attributed to *Mastodonsaurus jægeri*,[5] a Labyrinthodont, yet this is the first instance in which such specimens have been definitely referrred; consequently this will be a new record for the Rhætic of Britain.

Some of the teeth of *Ceratodus*, collected in 1891 and 1892, are interesting as having, in the case of the mandibular teeth, parts of the splenial attached, and in the palatal teeth parts of the palato-pterygoid.

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9. *Note on a Fault at Cinder Hill.* *By* GEORGE FOWLER, *M.Inst.C.E., F.G.S.*

The underground observation of faults which are visible on the surface, and are thus familiarly known, affords points of vantage for the elucidation of various facts in connection with them, which mere surface examination cannot afford. It has been the author's good fortune to trace below ground a series of 'faults,' of

[1] *Der Jura*, p. 33, and atlas, tab. ii.

[2] 'The Rhætics of Nottinghamshire,' *Q. J. G. S.*, 1882, p. 454.

[3] *Poissons Fossiles*, vol. ii. pt. ii. (1843), p. 84.

[4] *Ueber den Schädel eines fossilen Dipnoërs, Ceratodus Sturii* nov. spec., *aus den Schichten der oberen Trias der Nordalpen* (1891).

[5] Incorrectly determined as either a British genus or species; see Lydekker, *Catalogue of Fossil Reptilia and Amphibia*, vol. iv. p. 142.

which two are visible at the surface in the road leading by Cinder Hill Brickyard, and which are laid down on the maps of the Geological Survey.

There are three points in connection with this series of 'faults' which may be especially interesting to this Association, and which were illustrated on the section displayed on the screen.

The first point of interest is that whilst the 'throw' of the 'fault' in the Permian rocks at the surface only amounts to 76 feet, in the Coal Measures below the 'throw' amounts to 340 feet, a very much larger amount; and this shows that there was an enormous movement prior to the deposition of the Permian strata, and that there was a further small movement on the same lines after the deposition of the Permians. Both these movements took place when the rocks which they affected had obtained their full degree of induration, and it is obvious that the interval which elapsed between the two movements must have marked a long period of geological time.

The second point which is noticeable about this series of 'faults' is the great lateral movement of which it gives evidence. Whilst the 'throw' of the 'fault' on the slide or hade amounts to 340 feet, and the vertical displacement amounts to 210 feet, the horizontal movement amounts to 270 feet, showing enormous lateral movement.

A third point may also be noticed, which is, that the main fault, though a large one, practically makes no difference in the position of the zone of strata through which it cuts. If the coal seam on the left of the section shown be continued at its normal dip across the faulted ground, the position of the large 'fault,' it was seen that it practically meets the coal on the upcast or eastern side of that 'throw.' The rapid dip of the strata on the westward of the 'fault' line is thus merely the slipping of the different beds along the fractural edge of the fault, owing to the horizontal movement already indicated; and the fractures, the alterations in inclination, are the result mainly of horizontal and not of vertical movements.

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10. *On the Base of the Cambrian in Wales. By* H. Hicks, *M.D., F.R.S., F.G.S.*

If there is, as has been maintained by the author and others, a very marked unconformity at the base of the rocks usually classed as Cambrian in Wales, the evidence furnished by an examination of those basal beds which indicate shore condition is of the utmost importance. The author, therefore, in this paper gives a summary of the results bearing on this question which he has obtained in his examinations of these rocks in Wales.

Pembrokeshire.

St. David's.—The basal beds are exposed on the north and south sides of the pre-Cambrian Axis. Where faults do not intervene the lowest beds are rough conglomerates from 60 to 150 feet in thickness, in which pebbles over a foot in diameter are very frequently met with. The matrix and pebbles vary constantly, as they rest on different parts of the pre-Cambrian Axis, and there is the clearest evidence of an unconformity between the conglomerates and the highest beds of the Pebidian exposed in this area. The overlying beds, which are grits and sandstones, are ripple-marked, and show other proofs of having been deposited in shallow shore-water. The author has recently re-examined the basal beds in this area, and has accumulated additional evidence in support of the above view.

Ramsey Island.—The Cambrian conglomerates here rest on pre-Cambrian felstones and breccias. The pebbles are mainly well-rolled fragments of felstones cemented together by a felsitic matrix. Pebbles of quartzite and other materials are occasionally found, but the main amount of the material was undoubtedly derived from the rocks immediately underlying the conglomerates. The underlying rocks had undergone the marked changes now visible in them before the fragments in the conglomerates had been broken off.

Trefgarn.—The pre-Cambrian rocks in this area are mainly felstones of a peculiar type and volcanic ash. The conglomerates which repose on these rocks contain pebbles of large size, and have been proved by microscopical examination to be identical in character with the rocks on whose eroded surface they repose. Here again the marked similarity in the minutest particulars between the rolled fragments and the underlying rocks proves indisputably that the peculiar changes which these rocks have undergone must have taken place before the fragments were broken off, therefore in pre-Cambrian times.

Merionethshire.

Harlech Mountain.—Near the centre of the well-known anticlinal of Cambrian rocks in the Harlech Mountain there are conglomerates exposed which contain fragments of granitoid rocks, felstones, &c., in addition to pebbles of quartzites and quartz, and it is clear that they are, though not actually at the base, yet very near the base of the Cambrian rocks of that area. The most important conglomerates, however, in this district are those which were discovered by Professor Hughes and the author on the east side of the Trawsfynnydd Road, between Cae Cochion and Penmaen. Here they are seen resting unconformably upon an older series of rocks, and large fragments of the latter occur plentifully in the conglomerates.

Anglesey, and Caernarvonshire.

As Sir A. Geikie has recently admitted that many of the rocks in Anglesey, coloured on the Geological Survey Map of that island as 'altered Cambrian (and partly Silurian),' are 'undoubtedly far older than at least any of the Cambrian rocks of Anglesey or Carnarvonshire,' the evidence furnished by the basal beds where they rest on these rocks is highly important. The author was the first to point out, in a paper read before the British Association in 1879, that the patch near the centre of Anglesey coloured as 'intrusive granite chiefly of Lower Silurian age' contained within its boundary rocks of pre-Cambrian age, and evidently the oldest rocks in the island. (The rocks in this patch Sir A. Geikie now says appear to him to be 'unquestionably Archæan.') In the year 1884 the author further showed that the Cambrian conglomerates near Llanfaelog contained large pebbles of granitoid and other rocks, which, on microscopical examination, proved to be identical with rocks *in situ* in their immediate neighbourhood.

Professor Hughes has shown by fossil evidence that the beds which overlie the conglomerates near Llanerchymedd are of Upper Cambrian age, and, as these are separated by faults from the conglomerates and grits, it is clearly justifiable to classify these beds as the basal beds of the Cambrian in that area. The basal Cambrian beds near Beaumaris furnish equally convincing proofs of proximity to a shore-line composed of pre-Cambrian schists and felsitic rocks.

Bangor and Caernarvon.—The basal beds at and near Caernarvon described by Professor Hughes show clearly that they must have been deposited along a shore-line where granitoid and felsitic rocks were undergoing denudation, and the absence there of the usual thickness of overlying Cambrian rocks is due, the author believes, mainly to faults, but in part also to the unevenness of the pre-Cambrian land surface. There is much evidence in the various areas to show that the pre-Cambrian land surface was very irregular in character, and that the Cambrian sediments were accumulated along fairly well-defined lines of depression.

Bethesda, Llyn Padarn, and Moel Tryfaen.—The basal beds of the Cambrian in these areas, where not removed by faults, are also conglomerates, and the fragments in the conglomerates are mainly such as would be derived by denudation from the ridge of rocks in the neighbourhood which had been claimed by the author and Professor Hughes as of pre-Cambrian age. These views, put forward in the year 1877, were not accepted by the chiefs of the Geological Survey; but in the year 1891, in his anniversary address to the Geological Society, Sir A. Geikie admitted that the rocks in this ridge, 'variously termed quartz porphyries, felsites, and rhyolites,' were not intrusive in the Cambrian rocks, but 'the oldest

members of the volcanic series,' and that 'there is no true passage of the sedimentary rocks into it; on the contrary, the conglomerates which abut against it are in great part made out of its fragments, so that it must have been already in existence before these Cambrian strata were deposited.'

The grits and slates which overlie the conglomerates in these areas have always been classed by the Geological Survey as the Lowest Cambrian; therefore any attempt to extend the term Cambrian so that it might include the much older rocks which the surveyors had incorrectly marked as intrusive, and 'chiefly of Lower Silurian age,' the author thinks is unwarrantable. The error which caused the surveyors to class other pre-Cambrian rocks as 'altered Cambrian' equally renders it impossible to group these with the Cambrian, especially as in no instance has it been shown that the so-called 'altered Cambrian rocks' have their equivalents amongst the unaltered Cambrian rocks of the Survey. Moreover, it is certain that there is a marked unconformity at the base of the Cambrian (unaltered Cambrian of the Survey) in all the areas in Wales where the beds are seen to rest on the rocks classed by the author and others as of pre-Cambrian age.

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11. *On the Reptilia of the British Trias.* *By* E. T. NEWTON, *F.R.S.*

This communication is a review of our knowledge of the reptiles which have been recorded from the Triassic strata of Britain. In the first place attention is called to the teeth from Durdham Down, Bristol, described by Riley and Stutchbury in 1836 under the generic names of *Palæosaurus* and *Thecodontosaurus*, which, with additional specimens, were further described by Professor Huxley in 1869, he regarding them both as dinosaurian. The two genera are distinguished by the form of their teeth. Closely allied to *Palæosaurus* is the tooth described by Murchison and Strickland in 1837 as *Megalosaurus*, but subsequently named *Cladyodon* by Owen. Another and still larger tooth, from the same neighbourhood, has been referred by Professor Huxley to *Teratosaurus* (= *Zanclodon*): it is very similar to that of *Cladyodon*, but is more compressed, and has both anterior and posterior edges serrated to the base.

Rhynchosaurus articeps, from the Keuper of Grinshill, Shropshire, was described by Owen in 1841 from a skull, but was further illustrated by additional specimens, including other parts of the skeleton, described by Professor Huxley in 1887. This form, which is allied to the recent *Sphenodon*, is also near to the *Hyperodapedon*, remains of which have been found in the Elgin Sandstone and also in the Trias of Warwick and Devon. *Hyperodapedon* was made known by Professor Huxley in 1858, but first described it in 1869, and more fully in 1887 from a fine example now preserved in the British Museum.

Telerpeton Elginense, the celebrated lizard of the Elgin Sandstone, was found in 1850 by Mr. Patrick Duff, and described by Dr. Mantell in 1851 as having amphibian affinities. Additional examples were, however, described by Professor Huxley in 1867, who showed that its affinities were with the lacertilia, and not with the amphibia. *Telerpeton* is probably closely related to the living *Sphenodon*. *Stagonolepis Robertsoni* was really the first reptile found in the Elgin Sandstone; a series of scutes from Lossiemouth being thus named by Agassiz just fifty years ago (1843), but were thought by him to be the scales of a fish. The reptilian nature of this fossil was shown by Professor Huxley in 1858, and more abundant material has been described by the same writer in 1875 and 1877, which has established the crocodilian affinities of this Triassic reptile.

Dasygnathus longidens is the name suggested by Professor Huxley for a jaw with long teeth from the Elgin Sandstone, which had at first been referred to *Stagonolepis*. This form Professor Huxley thought might be dinosaurian, but additional information is much wanted to establish its true affinities.

The dicynodont remains, noticed by the present writer at the meeting of this Association last year at Edinburgh, have now been worked out, and the results, fully illustrated, will shortly appear in the 'Phil. Trans.' of the Royal Society. Four forms nearly allied to *Dicynodon* have been named *Gordonia Traquairi*,

G. Huxleyana, G. Duffiana, and *G. Juddiana*. Another dicynodont more nearly related to the *Ptychognathus* of Owen, but with a short muzzle and no teeth, has been named *Geikia Elginensis*.

The peculiar horned reptile, resembling the Moloch lizard, but apparently most nearly related to the South African *Pareiasaurus*, has been named *Elginia mirabilis*.

Work among the Elgin reptiles is still going on, and two entirely new forms are now made known for the first time. One of these was found by Mr. James Grant, of Lossiemouth; and, although the exact locality is uncertain, there is no doubt as to its being from the sandstone of the Elgin area. This specimen, which includes the skull (about three inches long) and the front part of the trunk, is evidently related to *Stagonolepis*.

The second new form was obtained by the Rev. Dr. Gordon from the Elgin Sandstone of Spynie Quarry, and will eventually be preserved in the British Museum. With the exception of the fore limbs and neck, nearly the whole of the skeleton has been preserved. Much of the skull has been very successfully cleared from the matrix by Mr. Richard Hall, of the British Museum, and was exhibited at a soirée of the Royal Society, when its resemblance to *Aëtosaurus* was pointed out by Mr. Arthur Smith Woodward. This reptile is of much interest, as it seems to be a form intermediate between the crocodiles and dinosaurs, being, apparently, related on the one hand to the Parasuchia and on the other to the theropodous dinosaurs. The skull is, in fact, that of a miniature megalosaur.

FRIDAY, SEPTEMBER 15.

The following Papers and Reports were read:—

1. *A joint Discussion with Section E on the Limits of Geology and Geography took place.* (*See p.* 834.)

2. *The Dissected Volcano of Crandall Basin, Wyoming.* *By* Professor Joseph Paxson Iddings.

The writer in exploring the north-eastern corner of the Yellowstone National Park and the country east of it came upon evidences of a great volcano which had been eroded in such a manner as to expose the geological structure of its basal portion.

The work was carried on as a part of the survey of this region under the charge of Mr. Arnold Hague, of the United States Geological Survey. This paper is an extract from a chapter in the final report on the Yellowstone National Park in process of completion, and the writer is indebted to Major J. W. Powell, Director of the Survey, and to Mr. Hague, chief of the division, for permission to present it at this time in anticipation of the publication of the final report.

The area of volcanic rocks described is but a small portion of the great belt of igneous material that forms the mountains of the Absaroka range, lying along the eastern margin of the Yellowstone Park. The volcano of Crandall Basin is one of a chain of volcanic centres situated along the northern and eastern borders of the Yellowstone Park, which are all distinguished by a greater or less development of radiating dikes, and by a crystalline core eroded to a variable extent.

The Palæozoic and Mesozoic strata which formed an almost continuous series to the coal-bearing Laramie had been greatly disturbed, and almost completely eroded in places, before the volcanic ejectamenta in this vicinity were thrown upon them. The period of their eruption is therefore post-Laramie, presumably early Tertiary.

The first eruptions of andesite were followed by those of basalt in great quantities, and these by others of andesite and basalt like the first. This was succeeded

by a period of extensive erosion, reducing the country to nearly its present form. Then came the eruption of a vast flood of rhyolite constituting the Park plateau, which was followed in this region by smaller outbreaks of basalt. The last phase of volcanic activity is found in the geysers and fumaroles which have rendered the region famous.

The volcano of Crandall Basin consists chiefly of the first series of basic andesites and basalts. The earliest acid andesite which occurs beneath these rocks appears to be the remnant of eruptions from neighbouring centres.

Nothing remains of the original outline of the volcano. The district is now covered by systems of valleys and ridges of mountain peaks that rise 2,000 to 5,000 feet above the valley bottoms. The geological structure of the country, however, makes its original character evident.

The outlying portions of the district to the south, west, and north consist of nearly horizontally bedded tuffs and subaërial breccias of basic andesite and basalt. With these are intercalated some massive lava flows, which are scarce in the lower parts of the breccia, but predominate in the highest parts above an altitude of 10,000 feet. Here they constitute the summits of the highest peaks.

In contrast to the well-bedded breccias around the margin of the district the central portion consists of chaotic and orderless accumulations of scoriaceous breccia with some massive flows. These breccias carry larger fragments of rock and exhibit greater uniformity in petrographical character.

A still more noticeable feature of the central portion of the district is the occurrence of dikes, which form prominent walls, and may be traced for long distances across the country.

The greater number of them are found to converge toward a centre in the highest ridge in the middle of the drainage basin of Crandall Creek. A small number converge towards a second centre three or four miles east of the first. In the southern part of the district there are many dikes trending towards a centre near the head of Sunlight Basin, about fifteen miles south of the Crandall centre.

The centre towards which the Crandall dikes converge is a large body of granular gabbro graduating into diorite. It is about a mile wide, and consists of numerous intrusions penetrating one another, and extending out into the surrounding breccia, which is highly indurated and metamorphosed in the immediate vicinity of the core. Within the area of indurated breccia the dike rocks become rapidly coarser-grained as they approach the gabbro core. This was undoubtedly the central conduit of an ancient volcano, the upper portion of which has been eroded away.

Upon comparing the geological structure of this region with that of an active volcano like Etna it is apparent that the lava flows which form the summits of the outlying peaks must have been derived from lateral cones fed by dikes radiating from the central conduit; and assuming that the volcano of Crandall Basin was similar in type to that of Etna, an idea of its original proportions is derived by constructing upon profile sections through the Crandall core the outline of Etna. If the erosion of the summits of the highest peaks is neglected the resulting height of the ancient volcano above the limestone floor is estimated at 13,400 feet. This is undoubtedly too low, and is well within the limits of present active volcanoes.

Erosion has removed at least 10,000 feet from the summit of the mountain to the top of the high central ridge in which the granular core is situated, and has cut 4,000 feet deeper into the valleys on either side. It has prepared for study a dissected volcano, which, it is hoped, will in time reveal some of the obscurer relationships existing between various phases of igneous rocks.

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3. *On Structures in Eruptive Bosses which resemble those of ancient Gneisses.* *By* Sir ARCHIBALD GEIKIE, *F.R.S.*

While it is now the general belief of geologists that the older granitoid and banded gneisses were originally eruptive masses, considerable difference of opinion exists as to the cause of the peculiar and characteristic structure which distinguishes gneiss from ordinary amorphous eruptive material. The pregnant sugges-

tion of Lehmann that this structure is essentially due to mechanical deformation has been widely accepted, and has undoubtedly been of great service in the investigations of the last ten years among pre-Cambrian rocks. That the foliation of many gneisses has arisen from the effects of enormous compression can no longer be disputed. But among these rocks other structures occur which cannot be satisfactorily so explained. In the granulitic gneisses, where the folia are thin, and where over considerable spaces a marked uniformity of lithological character prevails, crushing and recrystallisation have no doubt played a chief part in the production of the gneissic structure. But in the coarsely banded varieties, where thick layers of different chemical and mineralogical composition alternate irregularly with each other, mechanical deformation seems to be wholly inadequate to account for this arrangement. The author stated that he had pointed out some years ago that a close analogy might be traced between this banded character and certain structures to be observed in the deeper portions of large intrusive bosses. He had since then had opportunities of repeating and extending his observations, which had led him to the belief that the coarsely banded arrangement in the ancient gneisses was not due to any subsequent crushing and recrystallisation, but was a structure developed in the original, massive, or eruptive rock before its final consolidation. In the deeper-seated parts of intrusive bosses he had noticed that the component minerals had sometimes been segregated in parallel bands, each of which was marked by the predominance of one of them, and that the minerals had there crystallised in much larger forms than in the main body of the rock. Layers of felspar, pyroxene, olivine, and iron ores had in this way been separated out, and could be traced in alternate parallel bands for distances of many yards, sometimes even exhibiting puckered, folded, and inverted structures. Such segregations were so like the hornblendic, felspathic, quartzose, and pyroxenic bands of many gneisses that the observer could hardly at first believe that they were not portions of some ancient rock enclosed within the eruptive boss. He could soon convince himself, however, that they were really integral parts of the general mass. Not only is the banded structure of the gneisses perfectly reproduced in the bosses, but another equally characteristic structure, that of the pegmatite veins, is likewise simulated. Occasionally veins of this nature composed of the same minerals as the boss, but aggregated in different proportions, may be seen, not only in the main amorphous mass of the rock, but even traversing the segregated bands. So closely does this association of structures resemble that of the old gneisses as to impress the conviction on the observer that it probably represents the origin of some of the most conspicuous features in these rocks. Illustrations of the structures described may be found in eruptive bosses of Palæozoic age, but the best examples which the author has seen occur among the Tertiary gabbros of the Western Isles.

4. *On the Pittings in Pebbles from the Trias.* *By* Professor W. J. Sollas, *D.Sc., F.R.S.*

The singular indentations in the pebbles of the pebble beds of the Trias have been variously attributed to solution and pressure, and in limestone pebbles Sorby has conclusively shown how both have shared in their formation. No one, however, appears to have suggested the influence of slight movements as a powerful adjunct to pressure; and yet earth tremors are of such constant occurrence that slight movements must exist. How great may be the influence of these is proved by the incised bones of the great Irish deer, which have made sharp and deep cuts into each other wherever they have happened to lie in contact, and this although only under the pressure of a peat bog. Still better illustrations are afforded by some pebbles, to which my attention has been directed by my colleague Mr. MacHenry. These are from an ancient beach over which the tram line passes at Tritonville, Sandymount: they are covered with impressions essentially similar to those on the Trias pebbles, a result of the perpetual jarring produced by the passing trams. It is obvious that under the great pressure to which the Trias pebble beds have been exposed the slightest trembling at points of contact would produce similar or even more marked effects.

5. *On Bones and Antlers of* Cervus giganteus *incised and marked by Mutual Attrition while buried in Bogs or Marl.* *By* V. Ball, *C.B., LL.D., F.R.S.*

From time to time bones and antlers of this extinct deer have been found with peculiar cuts and marks upon them, which have suggested to some observers the work of man; careful examination has shown, however, that these cuts and polished and indented surfaces are all really due to the same cause, namely, the sawing or rubbing together of bones and antlers as they lay in contact while embedded in marl underlying peat. We cannot say with any degree of certainty what the cause of the movement may have been. It may perhaps have been due to alternate expansion and contraction, up and down, according to the amount of moisture in the bog; possibly, however, it was connected with earth-tremors, the origin and extent of which cannot be so easily explained.

The several finds of these cut bones, of which examples were exhibited to the Section, were made at Legan, five miles south of Edgeworthstown, Co. Longford; and on the left bank of the river Camoge, one mile from Lough Gur, and close to Kilcullen House, Co. Limerick.

In the former case, which was described by Professor Jukes in the year 1863, the bones lay in shell marl 2 or 3 feet thick, resting on blue clay (drift) and covered by 15 feet of peat; but originally, before being cut, the peat had been 50 feet thick at this spot. In the Lough Gur locality, which is described by Dr. Carte, the mode of occurrence of the bones was similar.

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6. *On a Mass of Cemented Shells dredged from the Sea Bed.* *By* Professor W. H. Herdman, *F.R.S.*

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7. *Note to accompany the Exhibition of a Geological Map of India.* *By* R. D. Oldham, *A.R.S.M., F.G.S., of the Geological Survey of India.*

Two maps are exhibited, on the scales of 96 and 32 miles to the inch respectively. The smaller is a chromo-lithograph, and will be published shortly with the second edition of that portion of the 'Manual of the Geology of India' which deals with the stratigraphical and structural geology of the Empire. The larger is a manuscript map representing in greater detail the state of our knowledge of Indian geology at the end of 1892.

It is well known that the Indian Empire is divisible into three geological regions, which are recognised as (1) the Peninsular, (2) the extra-Peninsular, and, separating them, (3) the Indo-Gangetic alluvium.

It is in the extra-Peninsular region that most of the additions to our knowledge of Indian geology have been made since the publication of a general map with the first edition of the 'Manual of the Geology of India.' The most important of these additions, so far as the area coloured goes, are in Upper Burma and the country explored by my colleague Mr. Griesbach while attached to the Afghan Boundary Commission; but, besides actual additions to the coloured area, great additions have been made to our knowledge of the stratigraphy and correlation of the rocks within the area which was coloured on the previous map.

Among the most important stratigraphical features of the extra-Peninsular area may be ranked the fine development, and abundant fossils, of the Lower Trias of the Central Himalayas; the rich fauna of this period, very scantily represented in Europe, is now under description, and the publication of the results must be looked forward to as an important addition to geological knowledge. Another feature is the very fine development of Cretaceous and Tertiary beds on the western frontier, and here the main stratigraphical break is not between the Cretaceous and Tertiary, but at the base of the Lower Cretaceous of accepted chronology.

Structurally the most important feature of the extra-Peninsular area is the great disturbance the beds have undergone, a disturbance which has taken place

principally within the Tertiary era, and mainly within the latter half of it. In fact, none of the mountains which bound the Indian Empire appear to have existed in anything like their present form or size at the commencement of the Tertiary era.

The Indo-Gangetic alluvium occupies a zone of depression formed entirely within the Tertiary era concomitantly with the elevation of the extra-Peninsular ranges. The surface deposits are all Recent or Pleistocene in age, but the occurrence of extinct mammals in the alluvium of the Jumna, some of which are identical with those of the uppermost Siwalik beds, points to an Upper Tertiary age of the deeper seated deposits of the Gangetic alluvium, whose thickness has been proved to reach 1,300 feet under Lucknow.

The Peninsular area differs from the extra-Peninsular in having been dry land since the close of the Palæozoic era, and in the very small amount of disturbance the rocks have undergone during this period. Two of its main geographical features appear to be of very ancient date. On the north-west the Aravalli range of the present day is the mere wreck of a mountain range whose elevation was completed in the Vindhyan period; the exact age of this system cannot be determined, as no fossils have been found in it, but it is certainly pre-Carboniferous, though probably not much older than Devonian. On the east the present coast-line appears to have been approximately determined about the same period, and the manner in which the small patches of marine deposits found on the east coast thin out against the older rocks shows that throughout the Secondary era the sea could never have extended much west of the present coast, though dry land may at times have extended further to the east.

The west coast appears to be of much more recent origin. Throughout the Secondary era there seems to have been a more or less continuous land connection between Southern India and South Africa; at the close of the Secondary era, however, this was broken up, the present west coast defined, and the range of the Western Ghats elevated. The palæontological evidence of the former connection between India and Africa is very complete, and, besides this, there is a very remarkable analogy between the geology of the two regions. The Karoo series of the interior of South Africa and the Uitenhage series of the coast are represented in India physically, stratigraphically, and palæontologically by the Gondwánas of the interior of the Peninsula and the Upper Gondwána outliers of the east coast.

So far reference has only been made to the most important features of what is known, and it will be well now to point out briefly what has still to be done. Within the thoroughly settled districts of the Peninsula large areas have been left uncoloured because absolutely nothing is known of them, and even in the area which has been coloured much remains to be done. The vast area coloured with one uniform tint of pink contains many varieties of rock, and at least two—probably many more—successive systems of deposits, besides intrusive and eruptive rocks of the most diverse kinds. The succession and correlation of the various rock systems which are classed as Transition, Cuddapah, and Vindhyan have yet to be established; while the relation between the Upper and Lower Gondwána beds and the proper classification of this great series of river deposits, ranging in age from Carboniferous to Cretaceous, have still to be worked out.

In the extra-Peninsular area the Himalayas have much information to yield, especially as regards the zonal distribution of the Siwalik fauna, and the sequence and correlation of the great series of as yet unfossiliferous slates and limestones of the North-west Himalayas. On the east our newly-acquired province of Burma, besides almost the whole of Assam, has to be surveyed, and the very fine series of Tertiary rocks and the economically important mineral deposits have to be examined in detail.

If fact, the most pressing need of the immediate future is not so much the exploration and imperfect examination of new regions as the completion and filling up of gaps in our knowledge of the geology of the land which lies within our frontier.

8. *Geological Sketch of Central East Africa.* By WALCOT GIBSON, *F.G.S.*

The tract of country described in this paper is situated in Equatorial East Africa. It extends from the coast inland to the N.W. borders of Victoria Nyanza.

The small island of Mombasa, the starting-point of the expedition, lies fifty miles north of the island of Pemba. A narrow creek, fordable at low water, separates the island from the mainland.

The sea cliffs are composed of coral rock, which also forms an inland belt about two miles broad, with a general elevation of 50 feet, which sometimes rises to 100 feet. A fringing reef borders the coast. The shore sand consists of comminuted corals and shells mixed with rounded fragments of quartz, orthoclase, garnets, and splinters of clear blue cyanite. These constituents appear to be derived from a submerged ridge, of which the Seychelles Islands are a remnant.

The coral rock rests on a sedimentary series consisting of shales, limestones, flaggy sandstones, grits, and conglomerates in descending order. The beds dip gently to the east. They extend inland to the borders of the Taru Plain, a distance of about forty-seven miles.

The beds are of marine origin, ammonites and ichthyosaurian remains having been found near Rabai and other localities.

It is impossible to correlate these beds with any occurring in South Africa, but they appear to form a belt running many miles north and south of Mombasa.

The sedimentary beds rest unconformably on a metamorphic series, consisting of gneisses, schists, and intrusive granites. The strike is N.N.W. and S.S.E., and the dip is generally high. The beds are often intensely folded (Ndange River). Biotite is the commonest mica, and orthoclase the predominant felspar. The schists contain much cyanite, full of iron inclusions. Common garnets are plentiful. Hornblendic rocks are remarkably scarce, the main mass being micaceous. Graphite schists occur, and the Bura Hills are largely composed of a crystalline limestone containing scales of graphite. No fossils could be detected. Quartz veins and quartzites are only feebly developed. They form gently undulating country or else nearly level plains (Taru, Serengeti) through which low isolated hills of gneiss and granite protrude.

It is evident that they have suffered enormous denudation. They no doubt represent a complex metamorphosed series of sediments and intrusive rocks, but of what geological age or ages it is impossible to state.

The intrusive granites are generally pegmatites. Porphyritic granite covers a large area in Kavirondo. Biotite is the essential mica, and a pink orthoclase the predominant felspar. The relation of this large mass of granite to the gneisses and schists could not be ascertained.

The area covered by granite and metamorphic rocks is enormous. Fully two-thirds of Central East Africa are composed of these rocks. The remaining portion of the country, excepting the narrow coast belt of sedimentary rocks, is formed of recent volcanic rocks.

No traces of the fossiliferous sandstones and shales found by Professor Drummond near Lake Tanganyika, and quite recently by Mr. Joseph Thomson to the west of Lake Nyassa and around Lake Bangweolo, were detected. If further investigation proves their absence from East Africa to be a fact, then we have in the deposits around Lake Tanganyika the most northerly extension of the Karoo beds of South Africa.

Volcanic rocks form the grandest scenery in East Africa. They occur in two forms, giving rise to two distinct types of scenery. They have either built up tall isolated mountains like Kilimanjaro (19,718 ft.), Kenia (18,000 ft.), Elgon (14,000 ft.), Chibchangani (12,000 ft.), besides numerous other smaller hills, or they are arranged in lines running north and south. The lavas, tuffs, and ashes composing the high central plateaux of Mau, Kamasia, and Lykipia have evidently issued from a north and south fissure. The site of this fissure is now occupied by the chain of lakes commencing with Naivasha on the south, and terminating northward in Lake Baringo. Along this line recent eruptions, some still giving out steam,

have broken out, and it is the interception of the drainage by the material thrown out from these vents that forms the lakes Naivasha, Nakuru, and Elmeteita.

Highly acid and ultra-basic rocks are represented. Kilimanjaro and the Kyulu Mountains are chiefly built up of basic rocks, while the lavas of Lykipia and the Mau plateaux are chiefly acid. It appears that the latter localities have been the seat from which acid lavas have continued to be poured from times prior to the first eruptions of Kilimanjaro up to the present day.

The basic lavas of Kilimanjaro do not extend very far from the original point of issue. At least this is so to the north, for no lavas were found on the plains of Lytokitok, distant thirty miles north of Kilimanjaro. On the other hand the acid lavas of Mau and Lykipia extend for great distances. Eastwards they stretch as far as the Athé plain, about fifty miles, and westwards to near the shores of Victoria Nyanza, a distance of nearly one hundred miles.

Further westward, in Busoga and Buganda, basic igneous rocks pierce the metamorphic rocks, but without possessing any general trend.

With the exception of the still active volcanoes it is impossible to state even the approximate geological age of any of the eruptions. Some of the volcanoes are possibly only dormant, others are certainly extinct, but none appears to be of great geological antiquity. All that can be safely asserted is that they are long subsequent to the deposition of strata containing ammonites, for, whereas the conglomerates of these sedimentary deposits contain pebbles of schist and gneiss, they nowhere yield fragments of igneous or volcanic rocks.

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9. *Report on the Volcanic Phenomena of Vesuvius.*—See Reports, p. 471.

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10. *On Quartz Enclosures in Lavas of Stromboli and Strombolicchio, and their Effect on the Composition of the Rock. By* Professor H. J. Johnston-Lavis, *M.D., M.R.C.S., B.-ès-Sc., F.G.S.*

In a recent dolerite lava stream that reaches the sea at Punta Pietrazza, on the island of Stromboli, are numerous inclusions of vein quartz and quartzite. These attain several centimetres in diameter; some specimens are almost clear glassy, while others are opaque and granular.

They have undergone more or less softening and fluxion, if not actual fusion, by the lava. They are surrounded by a glassy crust containing numerous augite crystals, more especially at the periphery. Where the glassy envelope has formed veins penetrating along the fissures in the quartz, augite crystals have crystallised out of this vitreous fluid. The amount of augite in the vicinity of these quartz enclosures is greater than the average in the surrounding lava, showing that the quartz has afforded a material necessary for the individualisation of augite. The crystallisation of such out of the glass envelope would have been more complete if sudden cooling of the lava had not prevented such a result.

The small island of Strombolicchio, close to Stromboli, is the wreck of an old volcanic neck. The rock composing it is lighter than the lavas of Stromboli, being of a purple tint, in which dark bottle-coloured and also bright emerald green augites are visible, the latter being fewer but very striking. The Strombolicchio rock is crowded with quartz enclosures, more opaque, more granular, and enwreathed with numerous emerald green augites. This green crust is seen microscopically to be composed of mixed grains of quartz and augite. We can trace the emerald green augites to an origin in the quartz which has combined with the residual fluid of basic oxides with insufficient silica for the individualisation of a mineral to form an augite.

The process is seen better here on account of the slow cooling of the plug and the absence of the mechanical disturbance in the flowing stream of lava of the Punta Pietrazza.

I have elsewhere shown the olivine nodules and many loose crystals are nothing more than altered limestone enclosures, and here we see quartz adding augite to a lava which may owe its diminished acidity in part to the absorption and conversion

of quartz into augite, the supply of the free silica possibly affecting the rock in other ways as to its composition, not so easily demonstrable as the one here described.

This is one more fact which goes to show that igneous rocks are markedly modified in their composition by the rocks they traverse. I have pointed out elsewhere that it is not a case of simple fusion or fluxion but rather one of selective diffusion.

11. *On the Gypsum Deposits of Nottinghamshire and Derbyshire.* *By* A. T. METCALFE, *F.G.S.*

The gypsum deposits of Nottinghamshire and Derbyshire belong to the Keuper series (Triassic). The 'Upper Marls,' in which the gypsum deposits occur, consist of beds of marls with minor bands of sandstone. Rock salt is apparently absent in both counties, but gypsum is abundant.

The chief gypsum works in Nottinghamshire are at Newark, Orston, Barton, Thrumpton Gotham, and Kingston, and in Derbyshire at Chellaston and Aston. The gypsum varies in thickness from a mere film to fifteen feet or so, and occurs in the marls in the form of 'bowls,' 'cakes,' beds, and thin bands or veins, and in every degree of purity. The more massive portions are usually saccharoidal or amorphous, and the purest kind is by the trade termed 'Superfine.' The tough variety, commonly called 'Alabaster,' which is worked up into ornaments, is found only in the Chellaston district. The thin bands or 'rivings' are fibrous ('satin spar'). These gypsum deposits were probably formed in salt lakes or inland seas, similar to the Dead Sea and the Great Salt Lake of Utah.

After extraction gypsum is cleaned, ground down to flour, and burnt. The burning drives off the combined water. When ground down to flour and properly burnt gypsum possesses the valuable property of recombining with water, and setting from a thin paste into a solid mass. The mineral thus treated forms plaster of Paris, and is an ingredient in Keene's and other hardened cements.

12. *Report on Photographs of Geological Interest.*—See Reports, p. 473.

13. *On a Bed of Oolitic Iron-ore in the Lias of Raasay.* *By* HORACE B. WOODWARD, *F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

The author drew attention to the occurrence in Raasay of a bed of oolitic iron-ore which had not been previously noticed. The bed in question attains a thickness of five feet, and lies at the top of the Middle Lias, beneath the dark shales of the Upper Lias. The stratigraphical position is thus approximately the same as that of the Cleveland iron-ore, although in Yorkshire the upper part of the Middle Lias contains a series of ironstone bands.

An analysis of the Raasay ore, made by Mr. A. B. Dick, showed in the grey (unweathered) rock 29 per cent., and in the brown (weathered) rock 37 per cent., of metallic iron. The discovery of the iron-ore was made during the progress of the Geological Survey.

14. *Note on a Transported Mass of Chalk in the Boulder Clay at Catworth in Huntingdonshire.* *By* A. C. G. CAMERON, *Geological Survey.*

[Communicated by permission of the Director-General of the Survey.]

In this paper the author comments upon the abundance of chalk fragments and boulders that culminate in the Drift around the highest points in the county west of the town of Huntingdon. At particular elevated spots there are outcrops of white Chalk which are dug up and used about the farmyards, where it sets hard,

making a firm bottom like cement. At Catworth, near Kimbolton, on the summit of high ground overlooking the plain of the Oxford Clay, there is a mass of chalk of great size, regularly interstratified with flint and lying on Boulder Clay. The very unusual phenomenon is presented of a village, or the greater and principal part of a village, built on chalk far away from any place where the Chalk formation occurs in place, or any outliers of that rock are seen. The evidence is striking. There are ponds and pits about in bare chalk, the soil in the gardens is chalk, and the graves in the churchyard leave off in chalk. There are numerous old excavations besides, whence hundreds of loads of chalk have been got out and carted away to the farms adjacent.

The flints in this chalk are angular, and show little signs of being weathered or worn, and there are in it besides thick tabular masses of flint. Copious springs issue at the base of this chalk, and it is therefore an important water-bearing bed in the village. The water in the wells sunk through the chalk to the clay beneath frequently runs over the top; while in that portion of the village which is outside the chalk area no water can be got by sinking in the clay. Besides Chalk there are boulders of other rocks clustered about this village, but none of notable size. It is not clear whether the Catworth Chalk is all one boulder—it may, perhaps, be several boulders with clay between—but as the material has been transported *unaltered* from the parent rock, it is not, in any sense of the term, a reconstructed chalk.

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15. *Augen Structure in Relation to the Origin of Eruptive Rocks and Gneiss.* *By* J. G. Goodchild, *F.G.S.*

The author discriminates between two types of augen structure—that (also termed phacoidal structure) in which the 'eyes' are not necessarily crystalline in structure, but are the unsheared portions of the rock which have escaped conversion into the schist to which their matrix has been reduced, and that in which the 'eyes' are crystalline minerals, generally undeformed, and of later date in origin than the movements which have produced the schistosity.

True augen structure occurs under two different conditions. In the one the constituents out of which the augen have been formed were already in existence within the rock, and their development in a crystalline form is merely a case of regeneration under plutonic conditions. In the other class of augen structure one or more of the essential constituents that go to form the 'eyes' did not originally exist within the rock, but have been introduced at a late period in its history from some foreign source.

Both of these classes of augen structure appear to be due to segregatory action, which came into play at a time when the rocks in which the structure occurs were in a potentially molten condition arising from the heat developed by earth movements acting under great pressure. Under these conditions of high temperature a slight and very gradual relief of the pressure referred to permitted some of the less refractory minerals to pass into a condition which favoured their segregating from a state of diffusion throughout the mass. Under these circumstances the more refractory minerals remained practically unaffected. If, following the diminution of pressure (which is equivalent in this case to a rise of temperature), there ensued a fall of temperature, the newly-formed minerals passed into the crystalline condition, while the rock material within which the augen had been developed still retained the schistose or other structure impressed upon it by the earth movements of prior date.

According to this view, therefore, phacoidal amphibolite and augen-amphibolite are respectively the results of mechanical and chemical action upon the same original type of rock.

In the other types of augen structure the 'eyes' are developed by the heat generated by earth movements, as in the former case; but an essential component of one or more of the constituents of the augen has been derived from an outside source. Augen of this class may consist of any one of several minerals; but those of most importance in the present connection are the

augen of one or other of the felspars. These consist of crystalline and, usually, very clear and fresh felspar, which has been developed, in the cases specially under consideration, in rocks of detrital origin, from whose original constituents the soluble alkalies had been removed by surface agencies. When such rocks were first acted upon by plutonic agencies they did not, therefore, contain the whole of the constituents out of which new felspar could arise. The question in such a case is, Whence came the alkalies which have combined with the silicates of alumina to form the felspar? In a few cases it may be surmised that part of the alkaline matter may have been introduced through the agency of percolating waters derived from a land-surface, or from the bottom of the sea. In such cases the alkalies liberated by the weathering are partly returned underground, there to enter upon a new cycle of change. But it is just possible that the chief source of most of the alkalies that are introduced into rocks in process of metamorphism may lie within the inner zones of the earth's crust, whence both potassium and sodium may be expelled in some mobile form capable of diffusing itself throughout certain kinds of rock, and there enter into new combinations in the manner already suggested.

Augen structure graduates into true pegmatite, in which certain rock-forming silicates have aggregated into zones or bands following the planes of structural weakness in the rock wherein they occur. True pegmatite is thus of *subsequent* origin to the consolidation of the rock in which it occurs: in this respect, amongst others, it differs from 'giant granites.' Pegmatite, according to this view, is not intrusive in the ordinary sense of the word, but is developed *in situ* as a consequence of local and slight relief of pressure when the parent rock was in a potentially molten state resulting from earth-creep under plutonic conditions.

The continued formation of bands of pegmatite along the dominant planes of weakness in a schistose rock of metamorphic origin must result in the development of a truly foliated (not schistose) rock, into whose structure crystalline felspar enters as an essential constituent. Such a rock would differ in no respect from a true gneiss.

If the superincumbent pressure is relieved *per saltum*, while any given rock is subjected to a temperature above that of the fusing point of its most refractory constituent, the entire mass enters into a state of fusion, in which form it eats its way upward until a communication is established between the subterranean zones of fusion and the surface, and a volcano is the result.

It would thus appear that augen structure is one of the first stages alike in the conversion of a metamorphic rock into gneiss, and in that fusion of deep-seated masses which eventually leads to the formation of the non-foliated rocks of eruptive origin.

SATURDAY, SEPTEMBER 16.

The following Papers and Report were read:—

1. *The Genetic Relations of the Basic Eruptive Rocks of Gran (Kristiania Region). By* Professor W. C. Brögger, *of the University of Kristiania.*

This paper dealt with a series of eruptive bosses and laccolites forming a line of hills, of which the chief, in order from north to south, are:—(1) Brandberget, (2) Sölvsberget, (3) Viksfjeld, and (4) Dignaes. The main rock type in these bosses was called by the author Olivine-gabbro-diabase. It is basic (43 per cent. SiO_2) in (1), rather less basic (47 per cent.) in (2), and somewhat acid (49 per cent.) in (4). From the intimate connection of the minerals in the different types, and the occurrence of all intermediate varieties, it was proved that these rocks had segregated in succession from a magma whose average composition was not unlike that of the rock of Sölvsberget. The gradation in chemical composition produced

a similar gradation in the mineral percentages, the felspar increasing from 12 per cent. to 64 per cent., and the pyroxene diminishing from 67 per cent. to 10 per cent. in a southerly direction. The author briefly stated that the contact metamorphism due to these plutonic rocks was quite different in character from that produced by a neighbouring mass of quartz-syenite in the same group of sedimentary rocks.

The eruptive bosses are accompanied by a great series of dikes and sheets of lamprophyric character, and varying from camptonite to bostonite. The author brought forward a quantity of evidence to prove that (1) these two extreme types, with SiO_2 percentages varying from 40 to 56, had been derived from the same magma; that (2) 9 parts of camptonite and 2 of bostonite (about the proportion observed in the field) would give a magma of the composition of the Olivine-gabbro-diabase of Sölvsberget; that (3) these lamprophyric dikes had been derived from the same magma as the plutonic rocks; and that (4) the differentiation had been effected while the magma still remained fluid. It was further shown that the differentiation was probably due to the migration of less soluble constituents to the cooling margin; that the camptonites had a composition closely allied to that of the brown hornblendes of the area; and that, while the essential cooling of the plutonic rocks had taken place in the eruptive bosses themselves, the dike rocks had segregated before extrusion.

A subsidiary differentiation of the plutonic rocks has also taken place in some of the bosses, giving rise in the pure basic Brandberget to a pyroxenite (with 95 per cent. pyroxene) and augite-diorite, and in the less basic Sölvsberget pyroxenite and labrador-porphyrite.

Other points of information to be noted were: (1) That, under different physical conditions, not only various mineral aggregates, but rocks of varying chemical composition had resulted from the differentiation of the same magma; (2) that similar products result in this case from the segregation of an Olivine-gabbro-diabase magma as have elsewhere been derived from a magma that has produced nepheline-syenite; (3) that the direction of segregation, according to laws of crystallisation, throws considerable light on the order of volcanic eruptions from neighbouring centres.

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2. *Petrological Features of the Dissected Volcano of Crandall Basin, Wyoming.* *By* Professor JOSEPH PAXSON IDDINGS.

It will not be possible in an abstract to do more than present in the briefest manner the more salient features of the petrology of the rocks of this volcano. The rocks are mostly the same as those in various parts of the Yellowstone National Park, some of which have been described in another place. The older acid breccia consists of fragments and dust of hornblende-mica-andesite, hornblende-andesite, and hornblende-pyroxene-andesite. They are partly glassy and partly holocrystalline. In some places they appear to pass into the overlying breccia, but in others they have been eroded and weathered before the latter were thrown over them.

The upper breccia, which constitutes the main mass of the volcano, is basaltic as a whole. It consists of pyroxene-andesite and basalt, the latter predominating in the upper part of the accumulation. The massive flows, so far as investigated, are all basalt. The composition varies constantly within narrow limits. A great part of these rocks contain glassy ground mass.

The rocks constituting the dikes exhibit more variation than the breccias, though the majority of them are like the breccias in composition and habit, being basalt. They are generally more crystalline. A great many dike rocks resemble the basalts in outward appearance, but have no olivine, and are more crystalline. The absence of olivine appears to be due to the conditions which influenced the crystallisation of the rocks, and not to their chemical composition, for in some cases what appear in hand specimens to be decomposed olivines are found to be paramorphs after this mineral, consisting of grains of augite, magnetite, and biotite. As the rocks become more crystalline biotite becomes an essential constituent, the porphyritic minerals lose their sharpness of outline and assume some of the microscopical characteristics they possess in gabbro.

Within the core the coarsest-grained forms are gabbro. The composition varies in different parts of one rock mass, and also between different intrusions within the core. The transition is from a gabbro to a diorite with biotite and quartz; and the extreme variety is that form of granite called haplite, the range in silica being from 51·81 to 71·62 per cent. Fine-grained andesitic equivalents of diorite occur in dikes outside of the core, but none of the most siliceous varieties has been found outside of it.

From this it appears that towards the end of volcanic activity near the core the composition of the magmas became more and more siliceous, and the volume of the lava erupted smaller. But this change in composition was not uninterrupted, for there are evidences of the alternate eruption of basic magmas as well. Dikes of more siliceous rocks are traversed by later dikes of basic rocks. This has taken place both inside and outside of the core.

Some of these basic rocks are exceptionally low in silica for rocks of this region. They are all found at some distance from the core, with one exception, which is an intrusion within it. They are lamprophyric, and approach more or less closely camptonites, monchiquites, kersantites, and minettes. They are connected with the basalts of the region by mineralogical and structural transitions.

These exceptionally basic rocks are the chemical complements of the acid ones in the core, and appear to be among the latest eruptions. While they agree with one another in having a low percentage of silica, they differ in the relative abundance of magnesia, lime, and iron oxide on the one hand and of alumina, soda, and potash on the other.

As already pointed out by the writer in another place, the variability in composition of all the igneous rocks in this volcano illustrates one mode of differentiation of a magma at a particular centre of eruption. A comparison of the chemical and mineral composition of the rocks of this district furnishes additional evidence of the fact that magmas which are chemically similar will crystallise into different groups of minerals, according to the conditions through which they pass. Thus chemically similar magmas may form basalt under one set of conditions and gabbro under others, the first composed of plagioclase, augite, olivine, magnetite, and sometimes hypersthene, the second consisting of plagioclase, augite, hypersthene, and biotite, besides some magnetite, orthoclase, and quartz, with or without hornblende. Minerals, then, which are primarily functions of the chemical composition of rocks are also functions of the physical conditions affecting crystallisation.

Some of the conditions under which the molten magmas solidified within the dikes and core of the volcano of Crandall Basin may be inferred from a consideration of the geological structure of this ancient volcano. The magmas which solidified within that portion of the core now exposed and those in dikes within a radius of two miles must have occupied positions at nearly the same distance beneath the surface of the volcano—that is, at a depth of about 10,000 feet. The latter rocks were as deep or as abysmal as the former, and yet their degrees of crystallisation range from glassy to coarsely granular. The influence of pressure on the crystallisation is not recognisable either in the size of grain or the phase of crystallisation.

Marked changes in the crystallisation may be traced horizontally in the immediate vicinity of the core. They are rapid near the core, and are accompanied by the induration and metamorphism of the surrounding rocks. They are in great measure independent of the size of the rock-body, since narrow dikes within the core are coarse-grained, while much broader ones in the surrounding breccias are very fine-grained. It was unquestionably the differences in the temperature of the core-rocks and of the outlying breccias which affected the degree of crystallisation. The former must have been more highly heated than the surrounding rocks, and the magmas solidifying within them cooled much more slowly than those injected into the outlying parts of the volcano. In this case the depth at which the magmas solidified appears to have been of little moment in comparison with the temperature of the rocks by which they were surrounded.

The core of gabbro and diorite, with an intricate system of veins of middle-

grained porphyritic rocks, and radiating dikes of aphanitic and glassy lavas, encased in an accumulation of tuffs and breccias, with flows of massive lava, constitute an extinct or completed volcano. The central core consists of magmas that closed the conduit through which many of the eruptions had reached the surface. In solidifying they became coarse-grained. The question naturally suggests itself, Are these rocks any less volcanic than those that reached the surface? What part of a volcano is non-volcanic?

3. *Berthelot's Principle applied to Magmatic Concentration.* *By* ALFRED HARKER, *M.A.*, *F.G.S.*

The paper deals with that type of concentration in which an igneous rock-magma, supposed originally homogeneous, has been differentiated by accumulation of the more basic ingredients in the cooler marginal part of the liquid. The author tries to find a physical cause for this action by comparing such a magma with a *saturated* saline solution, and applying Berthelot's 'principle of maximum work' or the cognate one of 'most rapid degradation.' The migration of the least soluble ingredients to the part of the liquid most easily saturated would determine crystallisation, the process which in the case supposed would give the most rapid evolution of heat.

4. *On the Origin of Intermediate Varieties of Igneous Rocks by Intrusion and Admixture, as observed at Barnavave, Carlingford.* *By* Professor W. J. SOLLAS, *D.Sc.*, *F.R.S.*

The two principal kinds of rocks composing the mountain of Barnavave are a dark-coloured, almost black, gabbro and a light-coloured, almost white, granophyre. This extreme contrast in colour renders the study of their relations to each other in the field a comparatively easy task. The gabbro which overlies the granophyre was the first-formed rock, and had already cooled and solidified before the granophyre was injected into it. The injection of granophyre has been of the most searching character, and the rock can be traced from the parent mass through dykes of all gradations in size down to the minutest films and specks which fill cracks and cavities in and amongst the constituent minerals of the gabbro. The gabbro has thus become converted locally into the quartz gabbro of authors, and it is suggested that in other cases, as that of Carrock Fell, this rock has had a similar origin. The granophyre, on the other hand, contains fragments of the gabbro, ranging from great blocks down to mere crystal dust of its constituent minerals, labradorite and augite. It thus passes into hornblendic granophyre, the 'syenite' of the Survey. There is no evidence here, as has been erroneously supposed, of the differentiation of an originally homogeneous magma, and the minute granophyric dykes are neither contemporaneous nor segregation products. On the contrary, rocks of intermediate character have been produced from already differentiated and opposed types solely by admixture.

5. *On the Transformation of an Amphibolite into Quartz-mica-diorite.* *By* Professor W. J. SOLLAS, *D.Sc.*, *F.R.S.*

On the steep northern side of the upper lake of Glendalough, Co. Wicklow, a coarsely crystalline rock, weathering spheroidally, protrudes in a bold mass through the surrounding Ordovician mica-schists, which it welds at the junction into desmosite. It consists almost entirely of hornblende, possesses a specific gravity of 3·03, and analysed in bulk gives the following results:—

Silica	48·94
Alumina	10·54
Ferric oxide	7·38
Manganese oxide	·15
Lime	10·29
Magnesia	20·66
Water	2·54
	100·50

Great interest attaches to the remarkable change in character and composition which the rock undergoes on passing from its eastern to its western boundary: quartz and orthoclase as well as plagioclase felspar appear as additional constituents; simultaneously the hornblende becomes actinolitic, and gives rise to a profusion of black mica. From an amphibolite the rock changes into a quartz-mica-diorite.

Numerous veins of quartz traverse the adjacent schists, and can be traced on the western side of the amphibolite up to and into it; they contain potash felspar near the junction, and it is to their influence that the transformation of the amphibolite is unquestionably due.

Another instance is thus afforded of a rock of intermediate type resulting from the admixture of already differentiated material.

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6. *On some Igneous Rocks of South Pembrokeshire, with a Note on the Rocks of the Isle of Grassholme. By* F. T. Howard, *B.A., and* E. W. Small, *M.A., B.Sc.*

I. *Constitution of the District.*—The district is largely composed of rocks of Old Red Sandstone age with smaller patches of Silurian and Ordovician strata, bounded on the N. by Carboniferous rocks. The igneous rocks may be roughly divided into two groups: the first or northern group runs in a more or less E. and W. direction, and marks the southern boundary of the Culm, while the second (in the S.W.) occurs as isolated patches, associated principally with rocks of Silurian age.

II. Reference is given to the previous work of Kidd, De la Beche, Murchison, Aveline, Rutley, Hicks, Davies, and Teall.

III. *Detailed Description of the Igneous Rocks.*—(A) *Northern group.*—Subdivided into three distinct patches: (*a*) In S.E. running from Benton Castle N.W. to Rosemarket, and from Benton Wood to Waterless. Practically all the rocks of this patch are quartz felsites or rhyolites; several of them show good flow structure and spherulites; much alteration has occurred in places, and the rocks have become brecciated. At Waterless is a rock (marked as granite on the Survey map), composed of quartz and felspar, whose connection with the felsites is not very clear. (*b*) To N. and E. of the last, stretching from near Llangwm to beyond Tier's Cross. The rocks of this patch show great alteration, readily weathering down to a felspathic gravel. On the Survey map the patch is marked partly as syenite and partly as greenstone. Dr. Hicks describes the decomposed form of the rock seen in the railway cuttings at Johnstone as a granitoid rock, very similar to the Dimetian. Two large quarries at Annikell and Targate give the only good exposures of the unweathered rock, chiefly a coarsely crystalline aggregate of quartz and hornblende, with a gneissose structure. Microscopically some portions might be described as typical hornblende schist, others as quartz diorite, granitic in aspect. Mr. Watts suggests that this rock may possibly be allied to the soda granites of Leinster, described by Professor Sollas. Another rock, a highly quartzose granite with microcline, appears to be later than the diorite: it shows much evidence of crushing and straining. A greenish black fine-grained rock (macroscopically appearing to be an ordinary dolerite, microscopically showing fresh stumpy plagioclase set in large plates of hornblende, apparently of primary origin) seems to be intrusive into the quartz diorite. It is doubtless the rock referred to by Dr. Hicks as diabase; it should perhaps be called an *epidiorite*, or proterobase. (*c*) The third portion of group A runs from Romans Castle on a narrow strip past Walwyns Castle up to Talbenny, where the outcrop broadens and forms the cliffs of Goultrop Head. As described by Dr. Hicks, Mr. Davies, and Mr. Teall, the main rock appears to be an altered quartz diorite penetrated by a whiter granite; besides which there seem to be basic dykes, all more or less altered, some epidiorite, others hornblende schists. The rock at Walwyns Castle appears, however, to be a *felsite*.

(B) *Southern group.*—This group consists of a number of patches, which

appear on the Survey map as greenstone, between St. Ishmael's on the E., Dale on the S., Wooltack Park on the W., and Musclewick Bay on the N., including also Midland Island and part of Skomer. The rock seen in a small quarry at Crabhall was described by Mr. Teall as a somewhat basic porphyrite. What appears to be the same rock is found exposed in several places on the opposite side of the Mullock stream. At Marloes Sands the continuation of the Crabhall rock appears in the cliff as a black dense rock much traversed by quartz and epidote. Microscopically it is a perfect dolerite, generally ophitic in structure with plagioclase in augite plates, but sometimes granular; there seems to be some hypersthene, and serpentine is present, probably after the same mineral. From Marloes Beacon this rock seems to continue, until it appears in contact with Llandeilo rocks in Musclewick Bay. The rock found here, however, is shown by the microscope to be a felsite (probably a soda felsite), and not a variety of the dolerite.

At Martins Haven the same ophitic hypersthene dolerite is found which occurs at Marloes Beacon and in Marloes Bay.

IV. *Age of the Igneous Rocks.*—The age of these rocks appears to have been regarded by the Survey as post-Carboniferous, while some of them at any rate have been claimed by Dr. Hicks as pre-Cambrian. The felsites in the Benton area are almost entirely associated with beds of Old Red Sandstone, and there does not seem to be any satisfactory evidence of intrusion. Such a continuous mass of quartz felsite, with well-marked spherulitic and fluxion structure, seems to suggest rather a flow than an intruded mass. On this supposition the beds must be at least post-Silurian.

The rocks from Llangwm to Talbenny are in almost every instance associated with Llandovery beds on the one hand and Carboniferous strata on the other. The Carboniferous strata are reversed in dip, and the line of junction is in our opinion a line of *thrust*. The evidence seems to indicate that the rocks are not post-Carboniferous, the Culm measures being apparently unaltered near the junction, and that, judging by lithological character, they did not occupy their present position as a ridge in Llandovery, Old Red, or Carboniferous times. With regard to the southern area we could not find clear evidence of intrusion, all the chief junctions appearing to be faulted ones; still there seems to be little doubt that rocks microscopically similar rest on different measures of Silurian age.

Grassholme, a small island about seven miles from the mainland, but rarely visited, appears to be the continuation of the ridge from Wooltack Park and Skomer towards the S.E. corner of Ireland.

No clastic rocks were found, the main rocks being ophitic dolerite, with corroded augite and some bands of secondary epidote and quartz.

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7. *Notes on a Hornblende Pikrite from Greystones, Co. Wicklow.* *By* W. W. Watts, *M.A., F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

In this paper the author gave a description of a rock which forms a dyke in the Cambrian slates and grits of Greystones, in Co. Wicklow. It is a dark, dense, coarsely crystalline rock, showing large crystals of hornblende with lustre-mottling, owing to the weathering-out of olivine crystals. It becomes finer-grained at the margins. An analysis by Dr. Sullivan was added.

The hornblende is of the usual green type, and occurs in large crystals enclosing pseudomorphs of olivine, now made up of magnetite and probably a colourless amphibole. A colourless hornblende also occurs either as cores or borders to the green crystals. A third type of hornblende present shows few cleavage cracks and much magnetite dust. Apatite is a constituent, but there is no felspar in the rock. The margin of the dyke is much sheared and phacoidal in structure.

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8. *Report on the Registration of Type Specimens of Fossils.*

See Reports, p. 482.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *A Discussion on Coral Reefs, Fossil and Recent, was opened by* Professor W. J. SOLLAS, *F.R.S.*

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2. *Twenty Years' Work on the Younger Red Rocks (Permian and Trias). By* Rev. A. IRVING, *D.Sc., B.A., F.G.S.*

The author reviews the work done by himself and in collaboration with other geologists on the Permian and Trias since he commenced the study of them in the North Midlands more than twenty years ago. He shows why the use of the term 'Poikilitic' and its connotation was given up by him after further work in Britain and in Germany; that it is necessary to recognise (as the earlier writers had done) two distinct systems in these rocks; that the strata called 'Bunterschiefer' by Murchison are really the base of the Trias of Central Germany, and are sharply cut off from the Zechstein; that there is a distinct differentiation of the two systems from each other on physical as well as stratigraphical grounds, on account of the great difference as to the derivation of their materials in the relation the Permian and Trias bear to the adjacent older land.

The chief results of the author's work on the Red Rocks of Devon in the years 1887–1892 are then summarised; further evidence of the contemporaneity of the volcanic rocks and the breccia-sandstone series is given; and attention is drawn to the new edition of the 1-inch map of the Geological Survey, on which the Permians of Devon, as described by himself, are delineated. He regrets that he is not able to accept (for reasons given in his published papers) the delimitation of the Keuper, at the expense of the Bunter, which is adopted on that map, the base of the Keuper having been traced in the valleys of the Otter and the Sid.

Sections are added (i.) at Saltern Cove on the west side of Torbay; (ii.) at Kimberley, Notts, in which there is the plainest evidence of great unconformability between the Dyas or Permian and the older Palæozoic rocks.

The author concludes with a note on the probable physical history of the series of strata under consideration.

The following are the more important papers of the author herein referred to:—'The Geology of the Nottingham District' (*Proc. G. A.*, vol. iv.); 'Classification of the European Permian and Trias' (*Geol. Mag.*, 1882); 'Triassic Deposits of the Alps' (*Ibid.*, November, 1882); 'The Dyas and Trias of Central Europe' (*Q. J. G. S.*, August, 1884); 'The Permian-Trias Question' (*Geol. Mag.*, July, 1884); 'Report on the Permian and Trias' (*International Geol. Cong.*, London, 1888); 'The Red Rocks of the Devon Coast Section' (*Q. J. G. S.*, February, 1888); 'Supplementary Note' on the same (*Ibid.*, February, 1892); 'The Base of the Keuper in Devon' (*Ibid.*, February, 1893).

See also the following papers:—

H. B. Geinitz, 'On the Limits of the Zechstein,' &c. (*Nova Acta Acad. Leop.*, Dresden, 1885), and summary of the same by A. Irving (*Geol. Mag.*, May, 1885); E. Hall, 'On the Red Rocks of South Devon' (*Q. J. G. S.*, February, 1892).

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3. *On the Trias of the Midlands. By* Professor C. LAPWORTH, *F.R.S.*

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4. *On the Occurrence of Fossils in the Magnesian Limestone of Bulwell, near Nottingham. By* Baron A. VON REINACH *and* W. A. E. USSHER.

At Bulwell, near Nottingham, good sections are exposed in stone and brick pits. The stone pits exhibit from 5 to 20 feet of yellowish brown Magnesian limestones, in beds of from 3 inches to 1 foot, with rather irregular surfaces. The

limestone is very occasionally compact and sub-crystalline. It consists for the most part of an aggregate of recrystallised materials, giving it the appearance of a sandstone. Very occasionally quartz pebbles of small size are met with in the denser portion. Certain markings on the irregular bed surfaces, which resembled the rude internal casts of molluscs, led us to make a closer investigation, which, from feeble casts and cavities, as if resulting from the solution of shell matter, introduced us to certain proofs of the presence of organisms. These are in a very imperfect state of preservation, but enough of the form remains to confidently assert the presence of *Schizodus* and of *Aucella Hausmanni*, forms which characterise the Upper Magnesian limestone.

The fossil casts are plentiful, sometimes occurring through the stone for a thickness of 2 or 3 feet. Through their imperfect condition one can only say that the other casts suggested *Schizodus Schlotheimii*, *S. rotundatus*, *Edmondia*, *Gervillia antiqua*. In brick pits near the stone pits, over a floor of Magnesian limestone, we find a section of from 5 to 15 feet of red marly clay, with pale brown and greenish arenaceous beds and bands in places apparently dolomitic and resembling the Magnesian limestone below. These clays are immediately overlain by the Red sandstone (lower mottled) of the Bunter. Proceeding towards Nottingham sections of Bunter pebble beds are shown, exhibiting their false bedded courses, and containing occasional lines of pebbles or scattered pebbles of hard liver-coloured quartzite and other stones, amongst which we noticed fragments of igneous rock, one quartz porphyry being of a type familiar in Germany and in the Teignmouth breccias of the south-west of England. The marly clay with intercalated sandstones recalls the passage beds of marl and sandstone on the coast between Exmouth and Straight Point, though the latter are more than ten times its thickness.

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5. *Note on the 'Himlack' Stone near Nottingham.* *By* Professor E. Hull, *F.R.S.*, *F.G.S.*

Professor F. Clowes having expressed his opinion at a previous meeting of the Section[1] that the Himlack stone had been formed artificially by quarrying out the rock which formerly inclosed it, the author desired to controvert this statement, and maintained that this remarkable rock was a monument of natural denuding agency, either marine or atmospheric. Some thirty years since, when working on the Geological Survey, he had sketched and described this rock, as will be seen on reference to the Survey memoir 'On the Triassic and Permian Rocks of the Midland Counties' (1869), p. 34. The rock, which is 20 feet high, consists in its upper part of the 'pebble beds,' and in its lower of the 'lower mottled sandstone,' of the Bunter sandstone; and at the time the memoir was written the author considered the rock to be a remnant of marine denudation, an old sea-stack of the post-Pliocene period.

Its great antiquity is evinced by its name 'Himlack,' which is clearly a Celtic word.

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6. *On the Junction of Permian and Triassic Rocks at Stockport.* *By* J. W. Gray, *F.G.S.*, *and* Percy F. Kendall, *F.G.S.*

The Stockport section has for nearly thirty years been regarded as furnishing the typical illustration of an unconformity between the Permian rocks and the overlying Bunter. The Geological Survey memoir relating to the district gives the following three vertical sections:—

Heaton Mersey	Hope Hill	Stockport
West		East
Trias.	Trias.	Trias.
Permian marl, 129 feet.	Permian marl, 25 feet.	Permian marl (absent).
Permian sandstone.	Permian sandstone.	Permian sandstone.

[1] Page 745.

By a fortunate chance boreholes have within the last ten years been put down at each of the localities named; the authors have had opportunities of watching the progress of the work, and the investigation has yielded results entirely different from those previously recorded.

At the most easterly exposure a good brook section displays a considerable thickness of the marls. The details of the well sections are as follows:—

West	Heaton Mersey	Hope Hill	Stockport East
Bunter	—	—	—
Collyhurst marls.	143 feet 6 inches.	150 feet.	134 feet.

The authors consider that the close correspondence in thickness of the uppermost member of the Permian series in all three sections justifies the opinion that, whatever may be the case elsewhere, there is no evidence of unconformity at Stockport. The facts brought to light have an important bearing upon the question of water supply, and also encourage the expectation that coal may be profitably worked beneath the newer rocks at long distances from the western edge of the Cheshire coalfield.

7. *Note on some Molluscan Remains lately discovered in the English Keuper. By* R. Bullen Newton, *F.G.S., British Museum (Natural History).*

This communication directs attention to the discovery, by the Rev. P. B. Brodie and Mr. E. P. Richards, of some obscure impressions of lamellibranch shells in the green gritty marls of the Upper Keuper Sandstone of Shrewley, Warwickshire, which form the first evidence of a molluscan fauna from these beds as developed in this country. The matrix appears to be so peculiarly unfavourable for the retention of shell structure that it is doubtful whether any better material than the present will ever be forthcoming. The specimens indicate truly marine types, though on account of bad preservation only three of them could be selected for description as exhibiting certain characters in their contours and sculpturing, which might be of service in ascertaining their probable generic positions. *Estheria minuta* is the one invertebrate form hitherto recorded from the British Keuper; that is, excluding the Foraminifera described by Professor T. R. Jones and W. K. Parker,[1] which came from an alabaster pit at Chellaston, near Derby, and which were doubtfully referred by the authors to an Upper Triassic age. The very modern facies of the Foraminifera has suggested the highly probable idea that they were derived from superficial deposits.

Associated in the matrix containing these molluscan impressions are fragments of cestraciont spines and teeth (*Acrodus Keuperinus*) and a part of a carapace of the small phyllopodous crustacean, *Estheria minuta*.

The specimens described are identified as—

(1) *Thracia* (?) *Brodiei* (n. sp.).
(2) *Goniomya Keuperina* (n. sp.).
(3) *Pholadomya* (?) *Richardsi* (n. sp.).

Such generic forms as are represented here have not apparently been reported from rocks of a similar period on the Continent or elsewhere.

Fifteen specimens and a diagram accompanied the paper.

8. *Observations on the Skiddaw Slates of the North of the Isle of Man. By* Herbert Bolton, *Assistant Keeper, the Manchester Museum, Owens College.*

The Skiddaw slate group of the north of the Isle of Man consists of alternations of quartzites, schists, slates, and bedded volcanic ash, penetrated by intrusive sheets and dykes and ramifying quartz veins.

[1] 'On some Fossil Foraminifera from Chellaston, near Derby,' *Quart. Journ. Geol. Soc.*, 1860, vol. xvi. pls. 19, 20, pp. 452–458.

North of a line drawn from Port Mooar through Snaefell to Peel, the general dip of the slate is to the north-north-west at an angle varying from thirty degrees to nearly vertical.

The lowest beds exposed in this area crop at Port Mooar along the axes of a series of anticlinal folds, which occupy the whole of the bay and extend south to Gob-ny-Garvain. These beds consist of massive iron-stained quartzites and schists overlaid by well-bedded slates. Northwards, by St. Maughold's Head and thence to Ramsey, the slates dip steadily to the north-north-west, the angle of dip varying between fifty and sixty degrees. Several dykes cut through the slate, whilst quartz veins run in all directions. The dykes run very nearly in the line of strike, and at first sight appear bedded and not intrusive.

That the quartz veins originated subsequent to the dykes is seen by their penetrating the latter.

Interbedded with the slates are thick sheets of volcanic ash much resembling quartzites.

The slates of St. Maughold's Head have yielded *Palæochorda* and certain oval structures which are evidently organic.

In the neighbourhood of Ballure Glen and Ballastowel Hill, the slates are badly bedded, and full of irregular pebble-like inclusions, which give to the rock a brecciated appearance. These have yielded the cast of a trilobite much resembling *Asaphus* or *Æglina*, and also certain other structures which may possibly prove organic. North and north-west from Ballastowell, the Skiddaw slates consist of irregularly bedded iron-stained slates with interbedded volcanic ash, the latter often of considerable thickness.

Near Sully Glen Station occurs the singular and isolated hill of Cronk Lumark, made up of a 'shivery' slate. In a quarry on the north side of the hill specimens were discovered of *Dictyonema sociale* and of a new species not yet described.

A series of dip observations taken along Sully Glen, Tholt-e-Will, and over the summit of Snaefell, shows that the dip changes round towards the west, causing axes of the anticlinal folds to emerge on the west coast, a little to the south of Peel, where the cliffs exhibit a series of contortions and folds not unlike those of Gob-ny-Garvain and Port Mooar.

The conclusions deduced from these observations are as follows:—

(1) That the Skiddaw slates of the north of the Isle of Man dip north-north-west from an axis of folding which runs from Gob-ny-Garvain and Port Mooar on the east to a little south of Peel on the west.

(2) That there exists a series of contemporaneous beds of volcanic ash.

(3) That the Skiddaw slates are fossiliferous, and by their fossils show a relation with the Lingula Flags of the Cambrian.

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9. *On the Volcanic Phenomena of Japan.* *By* Professor J. Milne, *F.R.S.*

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10. *On the Radiolarian Cherts of Cornwall.* *By* Howard Fox, *F.G.S.*

The Mullion Island radiolarian cherts were first recognised by Mr. J. J. H. Teall, F.R.S., in rocks sent to him by the author last autumn, and a joint paper was read at the Geological Society's meeting, February 8 last, describing the manner in which they occur. Dr. Hinde accompanied the paper with a description of the species recognised and with micro-photographs of the individual organisms.

Last Easter Mr. Teall, Professor Lapworth, and the author traced these cherts for about 650 yards in the cliffs and on the foreshore from the south end of Nelly's Cove, near Porthallow, Meneage, to near Ligarath Point, south of the Nore Point. Subsequently the author has examined the coast and some inland districts between Helford River and Fowey, and has found other exposures in the following places:—

Pendoner Beach, Veryan (for about 1,000 yards).—Beds many feet thick at the west end of this beach, on which the raised beach rests. Angular fragments of

chert are enclosed in the raised beach, and in one place a mass of chert and slate cliff has been thrust over it, and thus the chert appears both above and below as well as in the raised beach. Towards the eastern end of this beach the chert beds become thinner and more impure and ferruginous, and the limestone beds become thicker and more numerous.

Portloe Point, Veryan.—Here several beds, varying from one to six inches in thickness, are seen for 20 yards in the volcanic breccia (or 'trappean conglomerate' of De la Beche) associated with some small amount of shale and grit, more or less decomposing from the presence of iron. Two small exposures are traced inland, one of which is 500 yards west of Portloe Point.

Pecunnen Cove, Gorran.—N.W. of the Dodman beds of chert are seen in perpendicular thinly laminated crushed dark slates for 60 yards, accompanied by numerous lenticles and bands of black quartzite and yellowish grey limestone.

Inland exposures are traced at intervals in a line extending for five miles inland from Pendoner Beach in a N.E. direction through the village of Veryan to Tolcarne Mill, north of St. Michael Caerhays. These cherts on the mainland are less pure than those in Mullion Island, and the structure of the individual organism is destroyed. Some specimens show signs of great shearing and crushing, and have no traces of radiolaria; others show shearing with slight traces of radiolaria, whilst others show no signs of crushing, and have clear round spaces, evidently due to radiolaria. In many of the specimens examined a considerable amount of ferric oxide has been formed by the decomposition and oxidation of pyrites, and possibly also of ferriferous carbonate. At Portloe Point the chert appears to pass into quartz.

The Meneage and Veryan cherts are associated with the well-known Ordovician quartzites of those districts, and appear to lie immediately under them; but the sequence is not absolutely clear, and no typical fossils have yet been found in the shales and slates with which the cherts are interbanded.

TUESDAY, SEPTEMBER 19.

The following Papers and Reports were read:—

1. *A Discussion on Geological Education was Opened by the Reading of the Following Papers by* Professors COLE *and* LEBOUR.

Geology in Secondary Education. *By* Professor GRENVILLE A. J. COLE, *M.R.I.A., F.G.S.*

This paper is intended to be introductory to a discussion of the methods of teaching geology, with a view to making the general results of research in that science more accessible as a branch of education.

The need for selection of subjects in modern education is fully admitted; but it is urged that, following on the study of elementary chemistry and physics, geology forms a subject of such far-reaching importance that it should be included in the general curriculum for boys and girls about the age of sixteen or seventeen.

The utility, in a technical sense, of such knowledge is not here insisted on. But everyone upon this earth should be capable of appreciating his surroundings, and particularly the past history of life upon the globe, if he is to be able to pass judgment upon current affairs, and to play his part as an individual organism.

It is urged that geology is as fundamentally important as history, and tends to modify very largely our conceptions of the relations between what is called 'antiquity' and ourselves. Besides this, in common with other natural sciences, it encourages a love of truth where statements can be safely made, and of reserve where assertions would be merely dogmatic.

The course suggested for all pupils is one in which mineral details are subor-

dinated, except where they are important in explaining the origin of certain broad features, such as familiar and local landscapes. It is proposed to avoid the use of microscopic sections, and rather to rely upon powdered specimens for the determination of the constituents of such simple rocks as are dealt with. The greatest stress for general purposes is to be laid upon an outline of stratigraphical geology, and its illustration by such beds, unconformities, &c., as may be exhibited in the environs of the school. The outdoor character of the study should be insisted on; and the fact that the broader generalisations of the science are based on the collation of local observations will not be among the least valuable results of the introduction of the subject into our educational systems.

On Geology in Professional Education. By Professor G. A. Lebour, *M.A., F.G.S., of the Durham College of Science, Newcastle-upon-Tyne.*

The author has for many years been engaged in teaching geology in a University college situated in a centre of great mining and manufacturing activity. The students with whom he had to deal were many of them, therefore, being educated for some branch or other of engineering, and took up the subject of geology with a view to its future utility rather than as an academic subject merely. For professional students of this type he thought that the ordinary geological courses in colleges of this kind were, as a rule, too long. In his own college, for instance, geology comprised two or three annual series of about ninety lectures each, with a field-day every week and a field-week every year, besides (for second and third year men) at least eight hours per week of laboratory work. This was not too long for men going up for title or degree examinations in geology, and still less was it too much for those, necessarily few in number, who intended to become professional geologists; but for future mining or civil engineers and managers of works he contended that it was excessive. Such men need not be trained into experts in geology. It was enough that they should leave their college with so clear a grasp of the principles of the science and such an insight into its methods that they should be enabled to understand the reports of the geological experts whom they might employ, and to distinguish between the real expert and the quack. At present the conclusions of a report are often all that appears practical to and all that is really read by the interested parties. This would be otherwise had they been taught to understand the reasons on which the conclusions are based. A sound knowledge of principles could alone give this competence, and this could be obtained in at most a single year's course of the length previously referred to.

But if he advocated shorter courses for professional students it must not be supposed that he was therefore in any way in favour of special courses for special men. There was but one geology, whatever be the future career of the learner. There was no more a 'geology for engineers' or a 'geology for agriculturists' than there was (as had been suggested years ago in 'Exeter Change') a 'geology for the blind' or a 'geology for rural postmen.' The principles were the same for all, though in the time to be spent and in the number and selection of the illustrative facts brought under the notice of students there was ample room for judicious adjustment.

In attempting to carry out those views he had been overwhelmingly impressed by the value of practical work. If, as Professor Cole had well urged, outdoor work was useful for schoolboys, it was doubly useful for older students. The field was to the geologist what the laboratory was to the chemist, and for petrology and palæontology geologists now needed laboratories of their own.

As regards field-work, he had found it useful to adopt a scheme in which the region examined by his students was treated as an unknown bit of country would be in the limited time at the disposal of the class; maps and reports were drawn up exclusively from the observations actually made, leaving out of consideration all points of which the knowledge had been derived from other

sources. This method gave a sense of the reality of the work scarcely attainable otherwise.

Practical petrological work he had found generally popular with professional students—much more so than palæontological museum work, some of which must, however, of course, be done.

He thought that much more use than is commonly the case might be made of the experimental method in teaching students of this class. He found, for instance, that a machine designed by himself for the reproduction on the lecture-table of most of the phenomena connected with folds, faults, and thrusts gave great definiteness to the ideas of his pupils, and at the same time added very much to the interest taken in the lectures. This was the case also with many of Daubrée's experiments on lamination and foliation, and on joints produced by torsion, which could easily be adapted for demonstration purposes. The fact that sediment is deposited more rapidly in salt than in fresh water once seen is never forgotten—if only mentioned it is seldom remembered. The production of tinstone (cassiterite) in a porcelain tube from chloride of tin and water vapour can be managed within an hour's lecture, and impresses upon the student's mind one method of vein-filling from below in a manner unequalled by any amount of talk. The synthesis of several minerals can also, with a little trouble, be carried out with the best effects where a friendly chemical or metallurgical laboratory is at hand.

Added to experiments such as these, actual measurements with goniometers, observations of specific gravity by various methods, testings of hardness, streak, fusibility, and the like, should be made; and now that we had the benefit of Professor Cole's most excellent 'Aids in Practical Geology,' they could be made with much greater ease than formerly.

Time precluded the author from entering into further detail, but he trusted that enough had been said to show that in teaching professional students of the University College order he was inclined to rely very largely upon general principles, illustrated as far as possible by lecture experiments and by actual work done by the students themselves in the field and geological laboratory.

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2. *The Glaciation of Asia. By* Prince Kropotkin.

There has lately been a good deal of discussion about the glaciation of Asia, and especially of Siberia.

To speak of the glaciation or non-glaciation of an immense continent, without taking into account its orographic structure, is evidently utterly misleading. One must have first a clear idea of what Asia is from the orographer's point of view.

I have, therefore, marked what is known about the glaciation of Siberia upon a map, in which Petermann has embodied the ideas I advocate about the orography of Siberia. The different tints with which it is coloured will show at a glance the structure of that part of the continent.

Lilac represents the plateau (12,000 to 16,000 feet high in the south, 4,000 to 5,000 feet high in the north), with a depression—the lower plateau—coloured in a lighter shade of lilac. Deep and broad valleys penetrate into it from the west. They have been its drainage valleys. The high plateau has never been submerged since the Devonian age.

Brown colour represents the border-ridge of the plateau and the *Alpine tracts*, indented by deep valleys, which fringe the plateau and consist of chains running north-east (the older ones) and north-west (the younger ones).

Orange-yellow represents the high steppes and prairies, 1,000 to 2,000 feet high.

Green shows the lowlands under 1,000 feet, and mostly *under* 500 *feet*, above the sea.

Now, taking into consideration all that is known about the old glaciers of Siberia, we may, I think, sum it up as follows:—

The lowlands, in all probability, have *not* been glaciated. Immense portions of them were under the sea, perhaps during the Glacial age, and most certainly

during the post-Glacial period, up to what is now the 150 feet level, which means a great portion of the green space of the map.

Neither have the steppes, under 2,000 feet, been glaciated; but many mountain-ridges which rise over them (all under 6,000 feet) were covered with extensive glaciers.

The whole of the border-ridge *has* been glaciated. Immense glaciers in the Tian-Shan, and immense caps of ice further north, covered it, the ice being discharged into the typical longitudinal valleys which fringe the border-ridge, and descending there to a very low level (about 1,000 feet).

Ice also covered large parts and filled many valleys of the Alpine tracts which fringe the plateau. The secondary smaller plateaux, rising amidst these Alpine tracts (such as the Patom plateau, 58° north latitude, 115° east longitude, now 5,000 to 6,000 feet high), were totally buried under the ice. This suggestion of mine has now been confirmed by Obrucheff.

As to the plateau itself, I am very much inclined to think that the whole of the Vitim plateau and the north-west Mongolia plateau, east and south-west of Lake Baikal, were totally covered with an ice cap. So also the highlands further north.

There is reason to believe that the Pamirs were ice-bound in the same way, and the great extension of formidable glaciers in the Himalayas is fully proved in my opinion.

I also consider that the eastern border-ridge of the plateau—the Great Khingan—has been ice-bound. Where I have crossed it (50° north latitude) it bears traces of extensive glaciation.

As to the southern portion of the High Plateau—Tibet, Ordos, and highlands of the Hoang-ho, as also the highlands on the Amur in Manchuria and China—so far as my information goes, we must suspend judgment, and are sorry that we have no reliable information either in favour of or against glaciation. In fact, we know *nothing* in this respect as regards these countries.

But I must mention that the portions of North and Middle Asia which *have been* glaciated are, like the glaciated areas of Europe, always surrounded by a girdle of *Loess*. In Turkestan and on the Lena, as well as in South Russia or on the Rhine, a fringe of Loess marks the outer limits of glaciation; and those geologists who consider Loess intimately connected with glaciation, and as having been formed on the outer borders of large glaciers and ice caps, as it undoubtedly has been in the case of Europe, will see in the Loess of China an indication, though not yet a proof, of the probable extension of immense glaciers in the southern part of the Great Khingan, north and west of Peking, as well as in the Hoang-ho highlands.

I leave it to persons better acquainted than myself with the geology of Persia, Asia Minor, and Armenia to decide how far the south-western plateau of Asia has been invaded by ice.

My conclusion for Siberia and the adjoining parts of Mongolia might thus be provisionally expressed as follows:—

All regions now over 3,000 *feet of altitude have been covered either with ice caps on the plateaux, or with large glaciers in the Alpine tracts, the glaciers descending in the valleys to levels of about* 1,000 *feet above the sea. Regions below* 2,000 *feet have probably* NOT *been glaciated.*

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3. *On some Assumptions in Glacial Geology.*
By Professor T. G. BONNEY, *D.Sc., F.R.S.*

Three assumptions, often treated as axiomatic by modern glacialists, were discussed:—

(1) That boulder clays are ground moraines. The modes of transport of débris by ice were described. It was admitted that, the more extensive the glacier, the greater the amount (in proportion) of sub-glacial débris; but it was denied that there was any proof that such a deposit (ground moraine) ever attained a considerable thickness.

(2) That glaciers were potent excavators. It was shown that all the evidence pointed in the opposite direction, and that this dogma was irreconcilable with the former one.

(3) That ice can scoop loose material from a sea-bed, carry it overland, and deposit it unharmed far from and high above the water level. Instances were given from the Swiss lowlands to show the improbability of this hypothesis.

The deposits in this region differ from the British boulder clays (among other things) in the absence of lenticular intercalations of sand and gravel. These boulder clays are probably of more than one origin. They are not likely to be understood until there is more attention to facts and abstention from hypotheses.

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4. *On the Glacial Period, its Origin and Effects, and the Possibility of its Recurrence. By* C. A. LINDVALL, *of Stockholm.*

The author in this paper recalls the various explanations of the phenomena of the Quaternary period offered by different observers. Linné supposed the kames to contain the history of the first emergence of Sweden; Sepström (1836), Berzelius, Von Buch, and to a certain extent Sir A. Geikie, attributed the phenomena to a mighty current of water sweeping from north to south; Dr. Siljeström (1838) says that, even admitting the current, the upper valleys of Norway must have been marked by glaciers. Sir C. Lyell refers to geographical changes; Sir R. Ball calls in astronomical changes; but most modern geologists call in the action of inland ice.

The author's theory is that the phenomena are due to the continued action of ocean currents and loose drift ice. In Pleistocene times the Gulf Stream must have swept over Lapland and back through the archipelago of Northern Europe laden with drift ice. This ice, aided by tidal action and the gradual uplift of the land, is considered capable of moving and carrying large blocks of stone, masses of gravel and sand along the bottom of the sea, and of accounting for the denudation and striation of rocks and many other phenomena of the Glacial period in Sweden, Switzerland, Ireland, Norway, and North America.

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5. *Report on the High-level Shell-bearing Deposits at Clava, Chapelhall, and other Localities.*—See Reports, p. 483.

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6. *Report on Erratic Blocks.*—See Reports, p. 514.

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7. *On some Shell-middens in North Wales. By* P. W. ABBOTT *and* P. F. KENDALL, *F.G.S.*

The authors describe the occurrence of many well-preserved examples of *Cardium edule* and other species of edible mollusca exposed in a bank of earthy clay on the slopes of Penmaenmawr, about 200 yards from a farmhouse, 'the Quinta,' on the old road from Llanfairfechan to Conway. They regard them as kitchen-midden refuse, as they were associated with bones of birds, bits of charcoal, and a sheep's tooth. Traces of the foundations of huts were observed, but there was no remembrance remaining in the neighbourhood of any dwellings on the spot.

A second bed, in which the shells were extremely numerous, was observed in the Aber Valley, about 50 yards above the Bridge. It was exposed beneath the roots of a large tree which clung to the breached side of a fine terminal moraine, and the shell-bed presented the deceptive appearance of being overlaid by the materials of the moraine. The whole of the marine shells were of edible species, but it was remarked that the *interior* of a valve of Ostrea was encrusted with Polyzoa. The authors consider that both accumulations were brought together by human agency, and are of comparatively modern date.

8. *A Map of the Esker Systems of Ireland.*
By Professor W. J. SOLLAS, *D.Sc., F.R.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

Nowhere probably can the study of Kames or Eskers be more profitably undertaken than on the Central Plain of Ireland, over which they are strewn in countless numbers. Hitherto they have been investigated rather individually than collectively, though, thanks to the careful mapping of the officers of the Geological Survey, the material for establishing their connection as members of great groups or systems lies ready to hand.

Much, however, is to be learnt from the individual Esker. The current bedding of the masses of well-rounded pebbles and sand of which it is composed is such as to point to rapid accumulation in running water, while the numerous instances of irregular disturbance and 'caving in' can be most feasibly explained by the melting of enclosed masses of ice. One of the most striking peculiarities of form is the steepness of the sides, which frequently approaches the angle of repose of the constituent material, and forces upon one the idea of the existence during deposition of a sustaining wall, by which the running water was prevented from distributing its load far and wide over the surrounding plains. Such a wall might conceivably have been furnished by a previous lateral extension of the Esker itself, since removed by river action, but such a supposition is unsupported by evidence. A more probable suggestion is that the support was furnished by ice, and that the Esker may represent a 'cast,' as it were, of a glacier tunnel in gravel and sand. On this hypothesis all the known characters of Eskers find an explanation, and many incidental details, such as the long lakelet or shallow streams by which they are not unfrequently flanked.

All explanations of Eskers depending on marine action may be summarily dismissed, for not only do they fail to afford a single parallel instance to the point, but they are directly negatived by the universal absence of marine shells; of the thousands of existing Irish Eskers, not one has afforded a fragment of a contemporaneous marine fossil, in spite of most persistent and careful search. Either, then, we must admit, on the hypothesis of an Esker sea, that marine shells were absent from its floor over the whole breadth of Ireland, and through a bathymetrical range of 300 feet, or that having once existed they have since entirely disappeared. One alternative is not more improbable than the other, as is shown by the frequent occurrence of fragmentary marine shells in the sands and gravels of the Middle Glacial Drift, as on Ballyedmonduff and elsewhere at elevations of over 1,000 feet.

The fluviatile origin of Eskers, so ably advocated by the American geologists, Chamberlin, Lewis, and Wright, finds its strongest support in their relations to one another as parts of a system. In the map exhibited Eskers may be traced pursuing their winding, serpentine path for miles together, but at the same time with a convergence which ends frequently in their joining one by one together, like the tributaries of a river, to form a main stream. As with tributary rivers so here, the apices of the angles at the places of junction point in one general direction, that of the general convergence. From individual ridges also small spurs are frequently given off, usually including an acute angle, which points in the same direction as those made by the main branches. When, as sometimes happens, the direction is reversed, signs are not wanting that this is the result of a 'loop,' such as is so common in the course of undulating streams, and of which the Shannon, as it winds among the Eskers, affords instructive examples for comparison.

Accepting the fluviatile origin of Eskers, one may deduce from their present distribution that of the ancient drainage systems of the Irish glaciers. From the map two systems are clearly discernible, a smaller, corresponding to the glacier of Sligo and Roscommon, and the other vastly larger, embracing the whole Central Plain, with a general flow from west to east and a discharge probably by the basin of the Liffey.

9. *On some Shelly Clay and Gravel in North-east Aberdeenshire.* *By* DUGALD BELL, *F.G.S.*

This paper referred chiefly to a remarkable deposit of red clay, containing fragments of marine shells, which Mr. Jamieson, of Ellon, had described some years ago as occurring on the eastern border of Aberdeenshire, from sea-level up to about 300 feet.[1] This clay seems to be derived, not from the rocks of the district, but from rocks farther south, viz., in the Old Red Sandstone of Kincardine and Forfarshire. In short, land-ice from the southward appears to have come along the coast, bringing with it this red clay and other débris from the Old Red formation; and this conclusion is confirmed by the striæ on the projecting points along the coast.

The cause of this remarkable movement of the ice was, of course, the ice-blocked condition of the North Sea, as suggested by the late Dr. Croll in connection with Messrs. Peach and Horne's admirable paper on the boulder clay of Caithness.

But the difficulty with regard to this 'fine red mud' is that it seems to imply 'deep or at least quiet water' for its deposition. There is no evidence at the bottom of it of littoral mollusca, or of beach-sand and gravel between it and the underlying grey boulder clay of the district, so that 'it looks as if still water of some depth had at once taken the place of the glacier.'

This Mr. Jamieson accounts for by supposing that 'the ice did not break up till a considerable amount of submergence had occurred,' that deep-sea water at once took the place of the glacier, and received from it the red mud with fragments of shells taken up by it from some part of the sea-bed over which it had passed; and that these settled down immediately on the surface of the grey boulder clay; and this process he imagines to have begun at the extremity of the northward-moving glacier, in the neighbourhood of Peterhead, and to have crept southward along the coast as the ice gradually broke up.

To this there appear several weighty objections; but the one to be specially urged at present is this:—It was the ice-blocked condition of the North Sea that compelled the ice from the Old Red district to move northward along the coast from Stonehaven to Peterhead. As soon as this gave way the ice would undoubtedly pass on eastward out to sea. Where would it most likely give way first—if not to the south? So that before—probably long before—it was open sea at Peterhead, it would be more free and open at Stonehaven. What, then, could make the ice go northward, hugging the coast to Peterhead? The dominating factor in the case was the ice-blocked condition of the North Sea. While this continued, there could not be the deep still water there to receive the clay; when this ceased, there could not be the northward-moving glacier to bring the clay.

There seems to be but one way out of this dilemma. If deep and comparatively still water be required for the deposition of the clay, is it necessary to have recourse to a 'great submergence' in order to obtain it? Must it be *sea-water?* May it not have been accumulations of fresh-water caused by the ice passing across the transverse valleys and hollows, and so forming lakes along its margin wherein such sediments would accumulate? Mr. Jamieson has in the kindest and most candid way expressed his acceptance of this modification of his theory.

This is exactly parallel to what has lately been made out by Mr. Lamplugh in the neighbourhood of Flamborough Head;[2] and it is confirmed by the sagacious inference of the late Dr. Fleming, who, some fifty years ago, without knowing how such lakes could be formed, surmised that the clay had been deposited 'in some immense lake into which the sea only made a temporary irruption.' The author concluded by suggesting that this explanation might yet be found applicable to other localities, which had recently been the subject of investigation.

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[1] *Quar. Jour. Geol. Soc.*, vol. xxxviii. p. 160.
[2] *Ibid.*, vol. xlvii. p. 428.

10. *On the pre-Glacial Form of the Ground in Lancashire and Cheshire.* *By* C. E. De Rance, *F.G.S., of H.M. Geol. Survey.*

The author arrived at the following conclusions:—

1. The carving out of rock valleys has been mainly due to fluviatile action, operating before the Glacial period, when the land stood at least 300 feet higher above the sea-level than it does at present.

2. The valleys which lie below sea-level are entirely choked up by glacial drift, and absolutely concealed, and but for extensive boring operations their presence would never have been suspected.

3. The materials and irregular alternation of sequence of glacial material in the infra-sea-level valleys are identical with the character of the deposits above the sea-level.

4. There is now ample proof that these 'choked-up' valleys extend a considerable distance under the Irish Sea.

5. The glacial deposits extend up to 1,260 feet on the slopes of the Cumberland, Lancashire, Cheshire, and Carnarvonshire hills, margined by erratic blocks of large size that extend further and rise higher than the drift, and form a 'fringe' deposit, such as has been described in the United States, marking the limit of the margin of the ice-sheet, the highest boulder in Cheshire occurring at 1,364 feet.

6. The glacial deposits consist of (*a*) tough dark till with local fragments in the neighbourhood of shales, especially of Coal-measure age; (*b*) clay with local angular fragments of sandstone and a few erratic pebbles; (*c*) boulder clay, a red or reddish-brown clay passing into marl, which when washed contains rounded and glaciated grains of sand, of erratic origin, which are microscopic specimens of like shape and like origin to the boulders that occur in the clay, and which range in size up to 12 feet; (*d*) sands and gravels: these contain fragments of marine shells, up to 1,260 feet: these fragments are water-worn, often striated, and are themselves erratics. The author has never found two valves of a bivalve united; the species are representative of different 'depth zones,' and univalves contain sand or silt of a different character from the sand by which they are surrounded. The sands also contain fragments of all sizes of boulder clay, often angular and ragged, as if torn off; the sands are generally current-bedded, but often show distinct signs of 'fluxion structure,' and have been apparently formed partly in freshwater lakes and partly under land-ice.

7. Deep borings and sinkings invariably give a series of these clays and sands, often repeated eight or ten times over; consequently it is obvious that, though a bed of sand in one area may divide a bed of clay into an 'upper' and a 'lower boulder clay,' it is not only *not* certain that such upper boulder clay is on the same horizon as the local upper boulder clay in an adjacent area, but it is exceedingly improbable that it should be so.

8. The average thickness of the alternations of boulder clay and sands is such that, as a rule, the deepest Lancashire and Cheshire drift valleys of 80 to 150 feet disclose sections of the first three members of the series, and fully justify Professor Hull's classification of an upper and lower boulder clay, divided by a middle sand and gravel, often called the 'middle drift.' Had the beds been thinner, the true succession would have at once been recognised as far more numerous than the three-fold sequence observed by Professor Hull.

9. The interior composition of a glacial drift mound, or of a drift plateau between two valleys, is nearly always delusive as regards the surface indications. A constant arrangement of the surface deposit in a drift mound is a base of boulder clay, a strip of sand, a wide slope of boulder clay, and a crest or ridge of sands and gravels. As a rule it is at once obvious that the clay on the upper slope is *overlying* the sand and gravel of the ridge, but as a rule it is far less obvious that the clay at the foot of the slope is really not *underlying*, as at first sight seems apparent, but *overlying* the upper boulder clay, and is 'plastered' over the sands and gravels of the mounds, which resemble in section the coats of an onion—beds of variable thickness of boulder clay surrounding and washing an internal core of sand and gravel.

10. In upland valleys filled with ordinary boulder clay the surface of the clay is often obscurely *terraced* with descending gradients, corresponding to the floor of the bottom of the rock valley, and is apparently due to gigantic flood-waters, which at lower levels deposited glacio-fluviatile gravels, 100 feet above the level of existing streams.

11. The irregular original deposition of drift mounds upon a plain (also formed of drift) encloses what the late Mr. Mackintosh, F.G.S., called 'mere-basins,' and the American 'kettle-holes': they are areas in which the natural drainage is obstructed, and formerly only flowed away by percolation through sand-banks at the sides. They were originally probably all filled with more or less water. Many of these meres still remain in Lancashire and Cheshire, and vary in size from a few yards to more than a mile across. They are now all more or less artificially drained. The sites of a very large number are indicated by thick peat mosses. These constantly are found resting directly on sand, showing that the outfall of the water in the sands, at the time of the growth of the peat, was closed.

12. The more closely the surface of the drift-covered ground in relation to its origin is studied, the more recent does the termination of the glacial episode appear to be.

WEDNESDAY, SEPTEMBER 20.

The following Papers and Report were read:—

1. *On the Distribution of Granite Boulders in the Clyde Valley.* *By* DUGALD BELL, *F.G.S.*

The object of this paper was to connect the granite boulders which are found in the neighbourhood of Glasgow, Helensburgh, Gonrock, &c., with a granitic tract recently described by Messrs. Teall and Dakyns, of the Geological Survey, as occurring in the mountainous region which lies between the head of Loch Fyne on the one hand and of Loch Lomond on the other ('Quar. Jour. Geol. Soc.,' May, 1892). This tract, which occupies about twelve square miles, contains at least two varieties of granite: a porphyritic variety, with large crystals of orthoclase, easily recognisable, and a non-porphyritic variety; also, near its margin or junction with the mica schist, bands of tonalite and diorite. These varieties correspond with boulders found in the Clyde valley, especially in its western part, and along the shores of the various lochs that open out from it. The supposition put forth many years ago by Mr. Smith, of Jordanhill,[1] that these boulders had been transported from the Ben Cruachan district, was not borne out by the characteristics of the rocks, and was opposed to all that was now known regarding the general glaciation of the district. In harmony with that glaciation, however, boulders from the Glen Fyne tract referred to, dispersed by Loch Fyne, Loch Eck, and the Holy Loch; by Loch Sloy, Loch Long, and the Gareloch; and in a much smaller proportion by Loch Lomond (the tract lying almost entirely to the western side of the watershed of that loch), could, it was evident, reach the various localities where they are now found. The author showed specimens of the granite referred to.

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2. *On the Derbyshire Toadstone.* *By* H. ARNOLD-BEMROSE, *M.A., F.G.S.*

Toadstone is a local name for the igneous rocks interbedded with the Carboniferous limestones of Derbyshire. It occurs in a district of 25 by 20 miles. The upper and lower portions of a bed are sometimes amygdaloidal. The spheroidal structure is often well marked, the columnar more seldom and less perfectly. Toadstone varies very much in the amount of weathering it has undergone. It

[1] *Researches in Newer Pliocene and post-Tertiary Geology*, pp. 12, 141.

often decomposes to a sort of clay containing nodules of less altered rock, so that it has been supposed that toadstone in some localities 'replaces' a bed of clay in others. For this reason, and also because of the loose way in which the word is used by miners, statements as to the number of beds of toadstone and of the presence or absence of ore in it must be accepted with reserve. Careful mapping over the whole district will be necessary to ascertain the actual number of beds. Two at least may be seen exposed in several places, and there may be three or even four beds. The Black Hillock shaft has been supposed to be one of the vents through which the toadstone came up to the surface, because the bottom of the rock was not reached. Farey, however, maintains that this bed was sunk through, and a careful examination of the mine heap and shaft shows that the dolerite is not coarse-grained, and that there is no trace of agglomerate or of tuff. An occurrence of lead ore in the toadstone of the Wakebridge mine was next described. The rock in which the ore occurred when examined under the microscope proved to be a decomposed olivine-dolerite. The ore was as good in the toadstone as in the limestone. That the toadstone is contemporaneous with the limestone is proved by it being interbedded with the latter, by the occurrence of stratified tuffs in various parts of the district, and by the non-alteration of the beds immediately above the igneous rock, though in one or two places a clay bed below it has been caused to assume a columnar structure.

Very many specimens have been collected from all the outcrops of toadstone, which are some fifty in number, and many of them have been examined under the microscope. The lavas consist mainly of olivine-dolerite, the augite being both in ophitic plates and in irregularly shaped grains. The rock is much more fresh and less amygdaloidal than has been generally supposed. The tuffs are in some cases well preserved, and the outlines of the lapilli very clearly defined. The author hopes shortly to finish the examination of these rocks, and to offer the details to the Geological Society.

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3. *Note on the Perlitic Quartz Grains in Rhyolite.* *By* W. W. Watts, *M.A., F.G.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

The author exhibited specimens of that variety of the Sandy Braes Rhyolite from County Antrim which was formerly called Perlite. A microscopical examination of the rock shows crystals of sanidine and grains of quartz embedded in a brown glass. The latter shows perlitic structure in great perfection. In addition, however, the grains of quartz exhibit a series of cracks, which are distinctly perlitic in character. Thus a structure which was supposed to be confined to glasses that have cooled rather rapidly is shown to occur rarely, but occasionally, in crystals. Hitherto only one case has been observed in which the cracks entered from the crystals to the matrix; the perlitic cracks in the two constituents for the most part are independent.

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4. *On the Minute Structure of the Skeleton of* 'Monograptus Priodon.' *By* Professor W. J. Sollas, *D.Sc., F.R.S.*

[Communicated by permission of the Director-General of the Geological Survey.]

Remains of *Monograptus priodon* in an exceptionally perfect state of preservation occur in the Silurian limestone of Barnham Hill, Co. Tipperary, and are exhibited in the official collection of the Geological Survey in Dublin. These have been examined in thin slices under the microscope, and as a preliminary result the author describes the structure of the wall.

Most of the sections are transverse and display the cœnosarcal canal and one hydrotheca; they measure a little over 1·5 mm. along the greater, and about 1 mm. along the shorter axis. The wall, 0·025 mm. in thickness, consists of black

carbonaceous material in a more or less fragmentary condition, but sufficiently continuous to enable the existence of three layers to be determined: an outer and inner, which are very thin, separated by a space, now filled with calcite, from a thicker middle layer, which measures from 0·005 to 0·01 mm. across. The middle layer sometimes breaks up into threads, and the superficial films have a reticular appearance, which may, however, be due to post-mortem changes. In the region of the virgula and also along the free edges of the thecæ the wall thickens, partly by an enlargement of the space between the layers, and partly by a thickening of the middle layer. Thus, in one example the total thickness of the wall in the virgular region is 0·075 mm., and of the virgula itself, which represents the middle layer, 0·037 mm.; similarly at the margin of the theca the total thickness was found to be 0·085 mm., the included middle layer measuring 0·045 mm. Thin threads of carbonaceous material extend from the middle to the superficial layers, and are particularly obvious in the thickened regions. The virgula would appear to possess no independent existence; it seems to be merely a thickening of the middle layer.

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5. *Report on the Circulation of Underground Water.*
See Reports, p. 463.

[Maps, specimens, and photographs of geological interest were exhibited each day in the Temporary Museum from 10 A.M. to 6 P.M.]

Section D.—BIOLOGY.

President of the Section—Rev. H. B. Tristram, M.A., LL.D., D.D., F.R.S.

THURSDAY, SEPTEMBER 14.

[For the President's Address see p. 784.]

The following Reports and Papers were read :—

1. *Report on the Zoology of the Sandwich Islands.*—See Reports, p. 523.

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2. *On the Zoology of the Sandwich Islands. By* D. Sharp, *F.R.S.*

The islands were formerly supposed to be rich in plant and comparatively poor in animal life. But the progress of knowledge is modifying this latter view. In 1880 Wallace in 'Island Life' furnished the following statistics as to this archipelago—viz.: birds, 43 species, 24 of them peculiar to the islands; land and fresh-water mollusca, 300 or 400 species, all peculiar; insects, scarcely anything known; plants, 689 species, 377 peculiar.

After one year's investigation by the committees of the British Association and of the Royal Society, and incorporating the recent results of the work of private naturalists, the figures are: birds, 78 species, 57 of them peculiar; land and fresh-water mollusca, 475 species, all peculiar; insects, 1,000 species, 700 of them peculiar; plants (according to Hillebrand), 999 species, 653 peculiar (many of those not peculiar being introduced by man).

But the investigations of the committees show that these results are very incomplete, at any rate in the case of the insects, which cannot be estimated at less than 3,000 species, 2,500 or 2,600 of the number being peculiar.

These numbers in the case of the fauna are less than those of approximately similar areas in less insular parts. Devonshire has 84 resident species of birds and 30 summer migrants. The insects amount to about 6,000 species, and the land and fresh-water mollusca to 97 species, the vascular plants being about the same in number as those of the Sandwich Islands.

But there has already been very great extinction in this latter area, much of it probably even before the discovery and appropriation of the islands by civilised man.

The working of the British Association and of the Royal Society committees seems to offer the only chance of investigating the fauna. The native creatures are extremely difficult to find, and the usual inducements to sportsmen and collectors are wanting; while the small population and the absence of great centres of intellectual activity in the islands render it very improbable that the work will be accomplished by residents in the archipelago, though these might give very valuable assistance.

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3. *Interim Report on a Digest of Observations on the Migration of Birds at Lighthouses.*—See Reports, p. 524.

4. *Report on the Zoology and Botany of the West India Islands.* See Reports, p. 524.

5. *Note on the Discovery of* Diprotodon *Remains in Australia. By* Professor W. STIRLING.

6. *The following Address, by* Rev. H. B. TRISTRAM, *F.R.S., President of the Section, who was not able to attend the Meeting, was read by* Sir W. H. FLOWER, *K.C.B., F.R.S.*

Address:—

IT is difficult for the mind to grasp the advance in biological science (I use the term biology in its wide etymological, not its recently restricted sense) which has taken place since I first attended the meetings of the British Association, some forty years ago. In those days, the now familiar expressions of 'natural selection,' 'isolation,' 'the struggle for existence,' 'the survival of the fittest,' were unheard of and unknown, though many an observer was busied in culling the facts which were being poured into the lap of the philosopher who should mould the first great epoch in natural science since the days of Linnæus.

It is to the importance and value of field observation that I would venture in the first place to direct your attention.

My predecessors in this chair have been, of recent years, distinguished men who have searched deeply into the abstrusest mysteries of physiology. Thither I do not presume to follow them. I rather come before you as a survivor of the old-world naturalist, as one whose researches have been, not in the laboratory or with the microscope, but on the wide desert, the mountain side, and the isles of the sea.

This year is the centenary of the death of Gilbert White, whom we may look upon as the father of field naturalists. It is true that Sir T. Browne, Willughby, and Ray had each, in the middle of the seventeenth century, committed various observations to print; but though Willughby, at least, recognised the importance of the soft parts as well as the osteology, in affording a key to classification, as may be seen from his observation of the peculiar formation, in the Divers (*Colymbidæ*) of the tibia, with its prolonged procnemial process, of which he has given a figure, or his description of the elongation of the posterior branches of the woodpecker's tongue, as well as by his careful description of the intestines of all specimens which came under his notice in the flesh, none of these systematically noted the habits of birds, apart from an occasional mention of their nidification, and very rarely do they even describe the eggs. But White was the first observer to recognise how much may be learnt from the life habits of birds. He is generally content with recording his observations, leaving to others to speculate. Fond of Virgilian quotations (he was a fellow of Oriel of the last century), his quotations are often made with a view to prove the scrupulous accuracy of the Roman poet, as tested by his (White's) own observations.

In an age, incredulous as to that which appears to break the uniformity of nature, but quick to recognise all the phenomena of life, a contrast arises before the mind's eye between the abiding strength of the objective method, which brings Gilbert White in touch with the great writers whose works are for all time, and the transient feebleness of the modern introspective philosophies, vexed with the problems of psychology. The modern psychologist propounds his theory of man

and the universe, and we read him, and go on our way, and straightway forget. Herodotus and Thucydides tell a plain tale in plain language, or the Curate of Selborne shows us the hawk on the wing, or the snake in the grass, as he saw them day by day, and, somehow, the simple story lives and moves him who reads it long after the subtleties of this or that philosophical theory have had their day and passed into the limbo of oblivion. But, invaluable as has been the example of Gilbert White in teaching us how to observe, his field was a very narrow one, circumscribed for the most part by the boundaries of a single parish, and on the subject of geographical distribution (as we know it now) he could contribute nothing, a subject on which even the best explorers of that day were strangely inobservant and inexact. A century and a half ago, it had not come to be recognised that distribution is (along, of course, with morphology and physiology), a most important factor in determining the facts of biology. It is difficult to estimate what might have been gained in the case of many species, now irreparably lost, had Forster and the other companions of Captain Cook, to say nothing of many previous voyagers, had the slightest conception of the importance of noting the exact locality of each specimen they collected. They seem scarcely to have recognised the specific distinctions of the characteristic genera of the Pacific Islands at all, or, if they did, to have dismissed them with the remark, 'On this island was found a flycatcher, a pigeon, or a parrot similar to those found in New Holland, but with white tail-feathers instead of black, an orange instead of a scarlet breast, or red shoulders instead of yellow.' As we turn over the pages of Latham or Shaw, how often do we find for locality 'one of the islands of the South Sea,' and, even where the locality is given, subsequent research has proved it erroneous, as though the specimens had been subsequently ticketed; as Le Vaillant described many of his South African birds from memory. Thus Latham, after describing very accurately *Rhipidura flabellifera*, from the south island of New Zealand, remarks, apparently on Forster's authority, that it is subject to variation; that in the island of Tanna another was met with, with a different tail, &c., and that there was another variety in the collection of Sir Joseph Banks. Endless perplexity has been caused by the *Psittacus pygmæus* of Gmelin (of which Latham's type is at Vienna) being stated in the inventory as from Botany Bay, by Latham from Otaheite, and in his book as inhabiting several of the islands of the South Seas, and now it proves to be the female *Psittacus palmarum* from the New Hebrides. These are but samples of the confusion caused by the inaccuracies of the old voyagers. Had there been in the first crew who landed on the Island of Bourbon, I will not say a naturalist, but even a simple-hearted Leguat, to tell the artless tale of what he saw, or had there been among the Portuguese discoverers of Mauritius one who could note and describe the habits of its birds with the accuracy with which a Poulton could record the ways and doings of our Lepidoptera, how vastly would our knowledge of a perished fauna have been enriched! It is only since we learned from Darwin and Wallace the power of isolation in the differentiation of species that special attention has been paid to the peculiarities of insular forms. Here the field naturalist comes in as the helpful servant of the philosopher and the systematist by illustrating the operation of isolation in the differentiation of species. I may take the typical examples of two groups of oceanic islands, differing as widely as possible in their position on the globe—the Sandwich Islands in the centre of the Pacific, thousands of miles from the nearest continent, and the Canaries, within sight of the African coast—but agreeing in this, that both are truly oceanic groups, of purely volcanic origin, the ocean depths close to the Canaries, and between the different islands, varying from 1,500 to 2,000 fathoms. In the one we may study the expiring relics of an avifauna completely differentiated by isolation; in the other we have the opportunity of tracing the incipient stages of the same process.

The Sandwich Islands have long been known as possessing an avifauna not surpassed in interesting peculiarity by that of New Zealand or Madagascar; in fact, it seems as though their vast distance from the continent had intensified the influences of isolation. There is scarcely a passerine bird in its indigenous fauna which can be referred to any genus known elsewhere. But, until the very recent

researches of Mr. Scott Wilson, and the explorations of the Honourable W. Rothschild's collectors, it was not known that almost every island of the group possessed one or more representatives of each of these peculiar genera. Thus, every island which has been thoroughly explored, and in which any extent of the primeval forest remains, possesses, or has possessed, its own peculiar species of *Hemignathus, Himatione, Phæornis, Acrulocercus, Loxops, Drepanis,* as well as of the massive-beaked finches, which emulate the *Geospiza* of the Galapagos. Professor Newton has shown that while the greater number of these are, probably, of American origin, yet the South Pacific has contributed its quota to this museum of ornithological rarities, which Mr. Clarke very justly proposes to make a distinct biological sub-region.

That each of the islands of this group, however small, should possess a flora specifically distinct suggests thoughts of the vast periods occupied in their differentiation.

In the Canary Islands, either because they are geologically more recent, or because of their proximity to the African coast, which has facilitated frequent immigrations from the continent, the process of differentiation is only partially accomplished. Yet there is scarcely a resident species which is not more or less modified, and this modification is yet further advanced in the westernmost islands than in those nearest to Africa. In Fuertaventura and Lanzarote, waterless and treeless, there is little change, and the fauna is almost identical with that of the neighbouring Sahara. There is a whin-chat, *Pratincola dacotiæ,* discovered by my companion, Mr. Meade-Waldo, peculiar to Fuertaventura, which may possibly be found on the opposite coast, though it has not yet been met with by any collectors there. Now, our whin-chat is a common winter visitant all down the West African coast, and it seems probable that isolation has produced the very marked characters of the Canarian form, while the continental individuals have been restrained from variation by their frequent association with their migratory relations. A similar cause may explain why the blackbird, an extremely common resident in all the Canary Islands, has not been modified in the least, since many migratory individuals of the same species sojourn every winter in the islands. Or take the blue titmouse. Our familiar resident is replaced along the coast of North Africa by a representative species, *Parus ultramarinus,* differentiated chiefly by a black instead of a blue cap, and a slate-coloured instead of a green back. The titmouse of Lanzarote and Fuertaventura is barely separable from that of Algeria, but is much smaller and paler, probably owing to scarcity of food and a dry desert climate. Passing, 100 miles further to sea, to Grand Canary, we find in the woods and forests a bird in all respects similar to the Algerian in colour and dimensions, with one exception—the greater wing coverts of the Algerian are tipped with white, forming a broad bar when the wing is closed. This, present in the Fuertaventura form, is represented in the Canarian by the faintest white tips, and in the birds from the next islands, Tenerife and Gomera, this is altogether absent. This form has been recognised as *Parus tenerifæ.* Proceeding to the north-west outermost island, Palma, we find a very distinct species, with different proportions, a longer tail, and white abdomen instead of yellow. In the Ultima Thule, Hierro, we find a second very distinct species, resembling that of Tenerife in the absence of the wing bar and in all other respects, except that the back is green like the European, instead of slate as in all the other species. Thus we find in this group a uniform graduation of variation as we proceed further from the cradle of the race.

A similar series of modifications may be traced in the chaffinch (*Fringilla*), which has been in like manner derived from the North African *F. spodiogena,* and in which the extreme variation is to be found in the westernmost islands of Palma and Hierro. The willow wren (*Phylloscopus trochilus*), extremely numerous and *resident,* has entirely changed its habits, though not its plumage, and I have felt justified in distinguishing it as *Ph. fortunatus.* In note and habits it is entirely different from our bird, and though it builds a domed nest it is always near the top of lofty trees, most frequently in palm-trees. The only external difference from our bird consists in its paler tarsi and more rounded wing, so that its power of flight is weaker, but, were it not for the marked difference in its habits and voice,

I should have hesitated to differentiate it. In the kestrel and the great spotted woodpecker there are differences which suggest incipient species, while the forests of the wooded western islands yield two very peculiar pigeons, differing entirely from each other in their habits, both probably derived from our wood-pigeon, but even further removed from it than the *Columba trocaz* of Madeira, and, by their dark chestnut coloration, suggesting that peculiar food—in this case the berries of the tree laurel—has its full share in the differentiation of isolated forms. If we remember the variability of the pigments in the food of birds, and the amount absorbed and transferred to the skin and plumage, the variability in the tints and patterns of many animals can be more readily understood.

One other bird deserves notice, the *Caccabis*, or red-legged partridge, for here, and here alone, we have chronological data. The Spaniards introduced *Caccabis rufa* into Canary, and *C. petrosa* into Tenerife and Gomera, and they have never spread from their respective localities. Now, both species, after a residence of only 400 years, have become distinctly modified. *C. rufa* was introduced into the Azores also, and changed exactly in the same manner, so much so that Mr. Godman, some years ago, would have described it as distinct, but that the only specimen he procured was in moult and mutilated, and his specimen proves identical with the Canarian bird. Besides minor differences, the beak is one-fourth stouter and longer than in the European bird, the tarsus very much stouter and longer, and the back is grey rather than russet. The grey back harmonises with the volcanic dark soil of the rocks of the Canaries, as the russet does with the clay of the plains of England and France. In the Canaries the bird lives under different conditions from those of Europe. It is on the mountain sides and among rocks that the stouter beak and stronger legs are indispensable to its vigorous existence. It is needless to go into the details of many other species. We have here the effect of changed conditions of life in 400 years. What may they not have been in 4000 centuries? We have the result of peculiar food in the pigeons, and of isolation in all the cases I have mentioned. Such facts can only be supplied to the generaliser and the systematist through the accurate and minute observations of the field naturalist.

The character of the avifauna of the Comoro Islands, to take another insular group, seems to stand midway in the differentiating process between the Canaries and the Sandwich Islands. From the researches of M. Humblot, worked out by MM. Milne-Edwards and Oustalet, we find that there are twenty-nine species acknowledged as peculiar; two species from South Africa and twenty-two from Madagascar in process of specification, called by M. Milne-Edwards secondary or derived species.

The little Christmas Island, an isolated rock 200 miles south of Java, only 12 miles in length, has been shown by Mr. Lister to produce distinct and peculiar forms of every class of life, vegetable and animal. Though the species are few in number, yet every mammal and land bird is endemic; but, as Darwin remarks, to ascertain whether a small isolated area, or a large open area like a continent, has been more favourable for the production of new organic forms, we ought to make the comparison between equal times, and this we are incapable of doing. My own attention was first directed to this subject when, in the year 1857–58, I spent many months in the Algerian Sahara, and noticed the remarkable variations in different groups, according to elevation from the sea, and the difference of soil and vegetation. The 'Origin of Species' had not then appeared; but on my return my attention was called to the communication of Darwin and Wallace to the Linnean Society on the tendencies of species to form varieties, and on the perpetuation of varieties and species by means of natural selection. I then wrote:[1] 'It is hardly possible, I should think, to illustrate this theory better than by the larks and chats of North Africa. In all these, in the congeners of the wheatear, of the rock chat, of the crested lark, we trace gradual modifications of coloration and of anatomical structure, deflecting by very gentle gradations from the ordinary type, but, when we take the extremes, presenting the most marked differences. . . . In the desert, where neither trees, brushwood, nor even undulations of surface

[1] *Ibis*, 1859, pp. 429–433.

afford the slightest protection to an animal from its foes, a modification of colour, which shall be assimilated to that of the surrounding country, is absolutely necessary. Hence, without exception, the upper plumage of every bird—whether lark, chat, sylviad or sand-grouse—and also the fur of all the small mammals, and the skin of all the snakes and lizards, is of the uniform isabelline or sand-colour. It is very possible that some further purpose may be served by the prevailing colours, but this appears of itself a sufficient explanation. There are individual varieties of depth of hue among all creatures. In the struggle for life which we know to be going on among all species, a very slight change for the better, such as improved means of escape from its natural enemies (which would be the effect of an alteration from a conspicuous colour to one resembling the hue of the surrounding objects), would give the variety that possessed it a decided advantage over the typical or other forms of the species. . . . To apply the theory to the case of the Sahara. If the Algerian Desert were colonised by a few pairs of crested larks—putting aside the ascertained fact of the tendency of an arid, hot climate to bleach all dark colours—we know that the probability is that one or two pairs would be likely to be of a darker complexion than the others. These, and such of their offspring as most resembled them, would become more liable to capture by their natural enemies, hawks and carnivorous beasts. The lighter-coloured ones would enjoy more or less immunity from such attacks. Let this state of things continue for a few hundred years, and the dark-coloured individuals would be exterminated, the light-coloured remain and inherit the land. This process, aided by the above-mentioned tendency of the climate to bleach the coloration still more, would in a few centuries produce the *Galerita abyssinica* as the typical form; and it must be noted that between it and the European *G. cristata* there is no distinction but that of colour.

'But when we turn to *Galerita isabellina*, *G. arenicola*, and *G. macrorhyncha*, we have differences, not only of colour, but of structure. These differences are most marked in the form of the bill. Now, to take the two former first, *G. arenicola* has a very long bill, *G. isabellina* a very short one; the former resorts exclusively to the deep, loose, sandy tracts, the latter haunts the hard and rocky districts. It is manifest that a bird whose food has to be sought for in deep sand derives a great advantage from any elongation, however slight, of its bill. The other, who feeds among stones and rocks, requires strength rather than length. We know that even in the type species the size of the bill varies in individuals—in the lark as well as in the snipe. Now, in the desert, the shorter-billed varieties would undergo comparative difficulty in finding food where it was not abundant, and consequently would not be in such vigorous condition as their longer-billed relations. In the breeding season, therefore, they would have fewer eggs and a weaker progeny. Often, as we know, a weakly bird will abstain from matrimony altogether. The natural result of these causes would be that in course of time the longest-billed variety would steadily predominate over the shorter, and, in a few centuries, they would be the sole existing race; their shorter-billed fellows dying out until that race was extinct. The converse will still hold good of the stout-billed and weaker-billed varieties in a rocky district.

'Here are only two causes enumerated which might serve to create, as it were, a new species from an old one. Yet they are perfectly natural causes, and such as I think must have occurred, and are possibly occurring still. We know so very little of the causes which, in the majority of cases, make species rare or common that there may be hundreds of others at work, some even more powerful than these, which go to perpetuate and eliminate certain forms "according to natural means of selection."'

It would appear that those species in continental areas are equally liable to variation with those which are isolated in limited areas, yet that there are many counteracting influences which operate to check this tendency. It is often assumed, where we find closely allied species apparently interbreeding at the centre of their area, that the blending of forms is caused by the two races commingling. Judging from insular experience I should be inclined to believe that the theory of interbreeding is beginning at the wrong end, but rather that while the generalised forms

remain in the centre of distribution we find the more decidedly distinct species at the extremes of the range, caused not by interbreeding, but by differentiation. To illustrate this by the group of the blue titmouse. We find in Central Russia, in the centre of distribution of the family, the most generalised form, *Parus pleskii*, partaking of the characters of the various species east, west, and south. In the north-east and north it becomes differentiated as *P. cyaneus;* to the south-west and west into *P. cæruleus* and its various sub-species, while a branch extending due east has assumed the form of *P. flavipectus*, bearing traces of affinity to its neighbour *P. cyaneus* in the north, which seems evidently to have been derived from it.

But the scope of field observation does not cease with geographical distribution and modification of form. The closet systematist is very apt to overlook or to take no count of habits, voice, modification, and other features of life which have an important bearing on the modification of species. To take one instance, the short-toed lark (*Calandrella brachydactyla*) is spread over the countries bordering on the Mediterranean; but, along with it, in Andalusia alone is found another species, *C. bœtica*, of a rather darker colour, and with the secondaries generally somewhat shorter. Without further knowledge than that obtained from a comparison of skins, it might be put down as an accidental variety. But the field naturalist soon recognises it as a most distinct species. It has a different voice, a differently shaped nest; and, while the common species breeds in the plains, this one always resorts to the hills. The Spanish shepherds on the spot recognise their distinctness, and have a name for each species. Take, again, the eastern form of the common song-thrush. The bird of North China, *Turdus auritus*, closely resembles our familiar species, but is slightly larger, and there is a minute difference in the wing formula. But the field naturalist has ascertained that it lays eggs like those of the missel-thrush, and it is the only species closely allied to our bird which does not lay eggs of a blue ground colour. The hedge accentor of Japan (*Accentor rubidus*) is distinguished from our most familiar friend, *Accentor modularis*, by delicate differences of hue. But, though in gait and manner it closely resembles it, I was surprised to find the Japanese bird strikingly distinct in habits and life, being found only in forest and brushwood several thousand feet above the sea. I met with it first at Chiusenze—6,000 feet—before the snow had left the ground, and in summer it goes higher still, but never descends to the cultivated land. If both species are derived, as seems probable, from *Accentor immaculatus* of the Himalayas, then the contrast in habits is easily explained. The lofty mountain ranges of Japan have enabled the settlers there to retain their original habits, for which our humbler elevations have afforded no scope.

On the solution of the problem of the migration of birds, the most remarkable of all the phenomena of animal life, much less aid has been contributed by the observations of field naturalists than might reasonably have been expected. The facts of migration have, of course, been recognised from the earliest times, and have afforded a theme for Hebrew and Greek poets 3,000 years ago. Theories which would explain it are rife enough, but it is only of late years that any systematic effort has been made to classify and summarise the thousands of data and notes which are needed in order to draw any satisfactory conclusion. The observable facts may be classified as to their bearing on the Whither, When, and How of migration, and after this we may possibly arrive at a true answer to the Why? Observation has sufficiently answered the first question, Whither?

There are scarcely any feathered denizens of earth or sea to the summer and winter ranges of which we cannot now point. Of almost all the birds of the holoarctic fauna, we have ascertained the breeding-places and the winter resorts. Now that the knot and the sanderling have been successfully pursued even to Grinnell Land, there remains but the curlew sandpiper (*Tringa subarquata*), of all the known European birds, whose breeding ground is a virgin soil, to be trodden, let us hope, in a successful exploration by Nansen, on one side or other of the North Pole. Equally clearly ascertained are the winter quarters of all the migrants. The most casual observer cannot fail to notice in any part of Africa, north or south, west coast or interior, the myriads of familiar species which winter there.

As to the time of migration, the earliest notes of field naturalists have been the records of the dates of arrival of the feathered visitors. We possess them for some localities, as for Norfolk by the Marsham family, so far back as 1736. In recent years these observations have been carried out on a larger and more systematic scale by Middendorff, who, forty years ago, devoted himself to the study of the lines of migration in the Russian Empire, tracing what he called the *isopipteses*, the lines of simultaneous arrival of particular species; and by Professor Palmén, of Finland, who, twenty years later, pursued a similar course of investigation; by Professor Baird on the migration of North American birds; and subsequently by Severtzoff as regards Central Asia, and Menzbier as regards Eastern Europe. As respects our own coasts, a vast mass of statistics has been collected by the labours of the Migration Committee appointed by the British Association in 1880, for which our thanks are due to the indefatigable zeal of Mr. John Cordeaux, and his colleague Mr. John Harvie Brown, the originators of the scheme by which the lighthouses were for nine years used as posts of observation on migration. The reports of that Committee are familiar to us, but the inferences are not yet worked out. I cannot but regret that the Committee has been allowed to drop. Professor W. W. Cooke has been carrying on similar observations in the Mississippi valley, and others, too numerous to mention, have done the same elsewhere. But, as Professor Newton has truly said, All these efforts may be said to pale before the stupendous amount of information amassed during more than fifty years by the venerable Herr Gätke of Heligoland, whose work we earnestly desire may soon appear in an English version.

We have, through the labours of the writers I have named, and many others, arrived at a fair knowledge of the When? of migration. Of the How? we have ascertained a little, but very little. The lines of migration vary widely in different species, and in different longitudes. The theory of migration being directed towards the magnetic pole, first started by Middendorff, seems to be refuted by Baird, who has shown that in North America the theory will not hold. Yet, in some instances, there is evidently a converging tendency in northward migrations. The line, according to Middendorff, in Middle Siberia is due north, in Eastern Siberia S.E. to N.W., and in Western Siberia from S.W. to N.E. In European Russia Menzbier traces four northward routes: (1) A coast line coming up from Norway round the North Cape to Nova Zembla. (2) The Baltic line with bifurcation, one proceeding by the Gulf of Bothnia, and the other by the Gulf of Finland, which is afterwards again subdivided. (3) A Black Sea line, reaching nearly as far north as the valley of the Petchora. (4) The Caspian line, passing up the Volga and reaching as far east as the valley of the Obi by other anastomosing streams.

Palmén has endeavoured to trace the lines of migration on the return autumnal journey in the eastern hemisphere, and has arranged them in nine routes: (1) From Nova Zembla, round the west of Norway, to the British Isles. (2) From Spitzbergen, by Norway, to Britain, France, Portugal, and West Africa. (3) From North Russia, by the Gulf of Finland, Holstein, and Holland, and then bifurcating to the west coast of France on the one side, and on the other up the Rhine to Italy and North Africa. (4 *a*) Down the Volga by the Sea of Azof, Asia Minor, and Egypt, while the other portion (4 *b*), trending east, passes by the Caspian and Tigris to the Persian Gulf. (5) By the Yenesei to Lake Baikal and Mongolia. (6) By the Lena on to the Amoor and Japan. (7) From East Siberia to the Corea and Japan. (8) Kamschatka to Japan and the Chinese coast. (9) From Greenland, Iceland, and the Faroes to Britain, where it joins line 2.

All courses of rivers of importance form minor routes, and consideration of these lines of migration might serve to explain the fact of North American stragglers, the waifs and strays which have fallen in with great flights of the regular migrants having been more frequently shot on the east coast of England and Scotland than on the west coast or in Ireland. They have not crossed the Atlantic, but have come from the far north, where a very slight deflection east or west might alter their whole course, and in that case they would naturally

strike either Iceland or the west coast of Norway, and in either case would reach the east coast of Britain. But if, by storms and the prevailing winds of the North Atlantic coming from the west, they had been driven out of their usual course, they would strike the coast of Norway, and so find their way hither in the company of their congeners.

As to the elevation at which migratory flights are carried on, Herr Gätke, as well as many American observers, holds that it is generally far above our ken, at least in normal conditions of the atmosphere, and that the opportunities of observation, apart from seasons and unusual atmospheric disturbance, are confined chiefly to unsuccessful and abortive attempts. It is maintained that the height of flight is some 1,500 to 15,000 feet, and if this be so, as there seems every reason to admit, the aid of land bridges and river valleys becomes of very slight importance. A trivial instance will illustrate this. There are two species of blue-throat, *Cyanecula suecica* and *C. leucocyana:* the former with its red-breast patch is abundant in Sweden in summer, but is never found in Germany, except most accidentally, and the other is the common form of Central Europe. Yet both are abundant in Egypt and Syria, where they winter, and I have, on several occasions, obtained both species out of the same flock. Hence we infer that the Swedish bird makes its journey from its winter quarters with scarcely a halt, while the other proceeds leisurely to its nearer summer quarters. On the other hand, I have more than once seen myriads of swallows, martins, sand-martins, and, later in the season, swifts passing up the Jordan Valley and along the Bukaa of Central Syria at so slight an elevation that I was able to distinguish at once whether the flight consisted of swallows or of house-martins. This was in perfectly calm clear weather. One stream of swallows, certainly not less than a quarter of a mile wide, occupied more than half an hour in passing over one spot, and flights of house-martins, and then of sand-martins, the next day were scarcely less numerous. These flights must have been straight up from the Red Sea, and may have been the general assembly of all those which had wintered in East Africa. I cannot think that these flights were more than 1,000 feet high. On the other hand, when standing on the highest peak in the Island of Palma, 6,500 feet, with a dense mass of clouds beneath us, leaving nothing of land or sea visible, save the distant Peak of Tenerife, 13,000 feet, I have watched a flock of Cornish choughs soaring above us, till at length they were absolutely undistinguishable by us except with field-glasses.

As to the speed with which the migration flights are accomplished, they require much further observation. Herr Gätke maintains that godwits and plovers can fly at the rate of 240 miles an hour (!), and the late Dr. Jerdon stated that the spine-tailed swift (*Acanthylis caudacutus*), roosting in Ceylon, would reach the Himalayas (1,200 miles) before sunset. Certainly in their ordinary flight the swift is the only bird I have ever noticed to outstrip an express train on the Great Northern Railway.

Observation has shown us that, while there is a regular and uniform migration in the case of some species, yet that, beyond these, there comes a partial migration of some species, immigrants and emigrants simultaneously, and this, besides the familiar vertical emigration from higher to lower altitudes and *vice versâ*, as in the familiar instances of the lapwing and golden plover. There is still much scope for the field naturalist in observation of these partial migrations. There are also species in which some individuals migrate and some are sedentary. *E.g.*, in the few primeval forests which still remain in the Canary Islands, and which are enshrouded in almost perpetual mist, the woodcock is sedentary, and not uncommon. I have often put up the bird and seen the eggs; but in winter the number is vastly increased, and the visitors are easily to be distinguished from the residents by their lighter colour and larger size. The resident never leaves the cover of the dense forest, where the growth of ferns and shrubs is perpetual, and fosters a moist, rich, semi-peaty soil, in which the woodcock finds abundant food all the year, and has thus lost its migratory instincts.

But why do birds migrate? Observation has brought to light many facts which seem to increase the difficulties of a satisfactory answer to the question. The

autumnal retreat from the breeding quarters might be explained by a want of sufficient sustenance as winter approaches in the higher latitudes, but this will not account for the return migration in spring, since there is no perceptible diminution of supplies in the winter quarters. A friend of mine, who was for some time stationed as a missionary at Kikombo, on the high plateau south-east of Victoria Nyanza Lake, almost under the equator, where there is no variation in the seasons, wrote to me that from November to March the country swarmed with swallows and martins, which seemed to the casual observer to consist almost wholly of our three species, though occasionally a few birds of different type might be noticed in the larger flocks. Towards the end of March, without any observable change in climatic or atmospheric conditions, nine-tenths of the birds suddenly disappeared, and only a sprinkling remained. These, which had previously been lost amid the myriad of winter visitants, seemed to consist of four species, of which I received specimens of two, *Hirundo puella* and *H. senegalensis.* One, described as white underneath, is probably *H. æthiopica;* and the fourth, very small, and quite black, must be a *Psalidoprocne.* All these remained through spring and summer. The northward movement of all the others must be through some impulse not yet ascertained. In many other instances observation has shown that the impulse of movement is not dependent on the weather at the moment. This is especially the case with sea birds. Professor Newton observes they can be trusted as the almanack itself. Foul weather or fair, heat or cold, the puffins, *Fratercula arctica*, repair to some of their stations punctually on a given day, as if their movements were regulated by clockwork. In like manner, whether the summer be cold or hot, the swifts leave their summer home in England about the first week in August, only occasional stragglers ever being seen after that date. So in three different years in Syria I noticed the appearance of the common swift (*Cypselus apus*) in myriads on one day in the first week in April. In the case of almost all the land birds, it has been ascertained by repeated observations that the male birds arrive some days before the hens. I do not think it is proved that they start earlier; but, being generally stronger than the females, it is very natural that they should outstrip their weaker mates. I think, too, that there is evidence that those species which have the most extended southerly have also the most extended northerly range. The same may hold good of individuals of the same species, and may be accounted for by, or account for, the fact that, *e.g.*, the individuals of the wheatear or of the willow wren which penetrate furthest north have longer and stronger wings than those individuals which terminate their journey in more southern latitudes. The length of wing of two specimens of *Saxicola œnanthe* in my collection from Greenland and Labrador exceeds by ·6 inch the length of British and Syrian specimens, and the next longest, exceeding them by ·5 inch, is from the Gambia. So the sedentary *Phylloscopus trochilus* of the Canaries has a perceptibly shorter wing than European specimens.

To say that migration is performed by instinct is no explanation of the marvellous faculty, it is an evasion of the difficulty. Professor Möbius holds that birds crossing the ocean may be guided by observing the rolling of the waves, but this will not hold good in the varying storms of the Atlantic, still less in the vast stretch of stormy and landless ocean crossed by the bronze cuckoo (*Chrysococcyx lucidus*) in its passage from New Guinea to New Zealand. Professor Palmén ascribes the due performance of the flight to experience, but this is not confirmed by field observers. He assumes that the flights are led by the oldest and strongest, but observation by Herr Gätke has shown that among migrants, as the young and old journey apart and by different routes, the former can have had no experience. All ornithologists are aware that the parent cuckoos leave this country long before their young ones are hatched by their foster-parents. The sense of sight cannot guide birds which travel by night, or span oceans or continents in a single flight. In noticing all the phenomena of migration, there yet remains a vast untilled region for the field naturalist.

What Professor Newton terms 'the sense of direction, unconsciously exercised,' is the nearest approach yet made to a solution of the problem. He remarks

how vastly the sense of direction varies in human beings, contrasting its absence in the dwellers in towns compared with the power of the shepherd and the countryman, and, infinitely more, with the power of the savage or the Arab. He adduces the experience of Middendorff among the Samojeds, who know how to reach their goal by the shortest way through places wholly strange to them. He had known it among dogs and horses (as we may constantly perceive), but was surprised to find the same incomprehensible animal faculty unweakened among uncivilised men. Nor could the Samojeds understand his inquiry how they did it. They disarmed him by the question, How now does the arctic fox find its way aright on the Tundra, and never go astray? and Middendorff adds: 'I was thrown back on the unconscious performance of an inherited animal faculty;' and so are we!

There is one more kind of migration, on which we know nothing, and where the field naturalist has still abundant scope for the exercise of observation. I mean what is called exceptional migration, not the mere wanderings of waifs and strays, nor yet the uncertain travels of some species, as the crossbill in search of food, but the colonising parties of many gregarious species, which generally, so far as we know in our own hemisphere, travel from east to west, or from south-east to north-west. Such are the waxwing (*Ampelis garrula*), the pastor starling (*Pastor roseus*) and Pallas's sandgrouse, after intervals sometimes of many years, or sometimes for two or three years in succession. The waxwing will overspread Western Europe in winter for a short time. It appears to be equally inconstant in its choice of summer quarters, as was shown by J. Wolley in Lapland. The rose pastor regularly winters in India, but never remains to breed. For this purpose the whole race seems to collect and travel north-west, but rarely, or after intervals of many years, returns to the same quarters. Verona, Broussa, Smyrna, Odessa, the Dobrudscha, have all during the last half-century been visited for one summer by tens of thousands, who are attracted by the visitations of locusts, on which they feed, rear their young, and go. These irruptions, however, cannot be classed under the laws of ordinary migration. Not less inexplicable are such migrations as those of the African darter, which, though never yet observed to the north of the African lakes, contrives to pass, every spring, unobserved to the lake of Antioch in North Syria, where I found a large colony rearing their young; and which, so soon as their progeny was able to fly, disappeared to the south-east as suddenly as they had arrived.

There is one possible explanation of the sense of direction unconsciously exercised, which I submit as a working hypothesis. We are all aware of the instinct, strong both in mammals and birds without exception, which attracts them to the place of their nativity. When the increasing cold of the northern regions, in which they all had their origin, drove the mammals southward, they could not retrace their steps, because the increasing polar sea, as the arctic continent sank, barred their way. The birds reluctantly left their homes as winter came on, and followed the supply of food. But as the season in their new residence became hotter in summer, they instinctively returned to their birthplaces, and there reared their young, retiring with them when the recurring winter impelled them to seek a warmer climate. Those species which, unfitted for a greater amount of heat by their more protracted sojourn in the northern regions, persisted in revisiting their ancestral homes, or getting as near to them as they could, retained a capacity for enjoying a temperate climate, which, very gradually, was lost by the species which settled down more permanently in their new quarters, and thus a law of migration became established on the one side, and sedentary habits on the other.

If there be one question on which the field naturalist may contribute, as lion's provider to the philosopher, more than another, it is on the now much disputed topic of 'mimicry,' whether protective or aggressive. As Mr. Beddard has remarked on this subject, 'The field of hypothesis has no limits, and what we need is more study'—and may we not add, more accurate observation of facts? The theory of protective mimicry was first propounded by Mr. H. W. Bates, from his observations on the Amazon. He found that the group of butterflies, *Heliconiidæ*, conspicuously banded with yellow and black, were provided with certain glands

which secrete a nauseating fluid, supposed to render them unpalatable to birds. In the same districts he found also similarly coloured butterflies, belonging to the family *Pieridæ*, which so closely resembled the others in shape and markings as to be easily mistaken for them, but which, unprovided with such secreting glands, were unprotected from the attacks of birds. This resemblance, he thought, was brought about by natural selection for the protection of the edible butterflies, through the birds mistaking them for the inedible kinds. Other cases of mimicry among a great variety of insects have since been pointed out, and the theory of protective mimicry has gained many adherents. Among birds, many instances have been adduced. Mr. Wallace has described the extraordinary similarity between birds of very different families, *Oriolus bouruensis* and *Philemon moluccensis*, both peculiar to the island of Bouru. Mr. H. O. Forbes has discovered a similar brown oriole, *Oriolus decipiens*, as closely imitating the appearance of the *Philemon timorlautensis* of Timor-laut. A similar instance occurs in Ceram. But Mr. Wallace observes that, while usually the mimicking species is less numerous than the mimicked, the contrary appears to be the case in Bouru, and it is difficult to see what advantage has been gained by the mimicry. Now, all the species of *Philemon* are remarkably sombre-coloured birds, and the mimicry cannot be on their side. But there are other brown orioles, very closely resembling those named, in other Moluccan islands, and yet having no resemblance to the *Philemon* of the same island, as may be seen in the case of the *Oriolus phæochromus* and *Philemon gilolensis* from Gilolo. Yet the oriole has adopted the same livery which elsewhere is a perfect mimicry. May it not therefore be that we have, in this group of brown orioles, the original type of the family, undifferentiated? As they spread east and south we may trace the gradation, through the brown striation of the New Guinea bird, to the brighter, green-tinged form of the West Australian and the green plumage of the Southern Australian, while westward the brilliant yellows of the numerous Indian and African species were developed, and another group, preferring high elevations, passing through the mountain ranges of Java, Sumatra, and Borneo, intensified the aboriginal brown into black, and hence were evolved the deep reds of the various species which culminate in the crimson of Formosa, *Oriolus ardens*, and the still deeper crimson of *O. trailli* of the Himalayas.

It is possible that there may be similarity without mimicry, and, by the five laws of mimicry as laid down by Wallace, very many suggested cases must be eliminated. We all know that it is quite possible to find between species of very different genera extraordinary similarity which is not mimetic. Take, for instance, the remarkable identity of coloration in the case of some of the African species *Macronyx* and the American *Sturnella*, or, again, of some of the African *Campophagæ* and the American *Agelæus*. The outward resemblance occurs in both cases in the red as well as in the yellow-coloured species of all four groups. But we find that the *Macronyx* of America and the *Campophagæ* of Africa, in acquiring this coloration, have departed widely from the plain colour found in their immediate relatives. If we applied Mr. Scudder's theory on insects, we must imagine that the prototype form has become extinct, while the mimicker has established its position. This is an hypothesis which is easier to suggest than either to prove or to disprove. Similar cases may frequently be found in botany. The strawberry is not indigenous in Japan, but in the mountains there I found a potentilla in fruit which absolutely mimicked the Alpine strawberry in the minutest particulars, in its runners, its blossoms, and fruit; but the fruit was simply dry pith, supporting the seeds and retaining its colour without shrinking or falling from the stalk for weeks—a remarkable case, we cannot say of unconscious mimicry, but of unconscious resemblance. Mimicry in birds is comparatively rare, and still rarer in mammals, which is not surprising when we consider how small is the total number of the mammalia, and even of birds, compared with the countless species of invertebrates. Out of the vast assemblage of insects, with their varied colours and patterns, it would be strange if there were not many cases of accidental resemblance. A strict application of Wallace's five laws would, perhaps, if all the circumstances were known, eliminate many accepted instances.

As to cases of edible insects mimicking inedible, Mr. Poulton admits that even unpalatable animals have their special enemies, and that the enemies of palatable animals are not indefinitely numerous.

Mr. Beddard gives tables of the results obtained by Weismann, Poulton, and others, which show that it is impossible to lay down any definite law upon the subject, and that the likes and dislikes of insect-eating animals are purely relative.

One of the most interesting cases of mimicry is that of the *Volucella*, a genus of *Diptera*, whose larvæ live on the larvæ of *Hymenoptera*, and of which the perfect insect closely resembles some species of humble-bee. Though this fact is unquestioned, yet it has recently given rise to a controversy, which, so far as one who has no claim to be an entomologist can judge, proves that, while there is much that can be explained by mimicry, there is, nevertheless, a danger of its advocates pressing it too far. *Volucella bombylans* occurs in two varieties, which prey upon the humble-bees, *Bombus muscorum* and *B. lapidarius*, which they respectively resemble. Mr. Bateson does not question the behaviour of the *Volucella*, but states that neither variety specially represents *B. muscorum*, and yet that they deposit their eggs more frequently in their nests than in the nests of other species which they resemble more closely. He also states that in a show-case in the Royal College of Surgeons, to illustrate mimicry, two specimens of another species, *B. sylvarum*, were placed alongside of the *Volucella*, which they do resemble, but were labelled *B. muscorum*.

But Mr. Hart explains the parasitism in another way. He states that a nest of *B. muscorum* is made on the surface, without much attempt at concealment, and that the bee is a peculiarly gentle species, with a very feeble sting; but that the species which the *Volucella* most resemble are irascible, and therefore more dangerous to intruders. If this be so, it is difficult to see why the *Volucella* should mimic the bee, which it does not affect, more closely than the one which is generally its victim. I do not presume to express any opinion further than this, that the instances I have cited show that there is much reason for further careful observation by the field naturalist, and much yet to be discovered by the physiologist and the chemist, as to the composition and nature of animal pigments.

I had proposed to occupy a considerable portion of my address with a statement of the present position of the controversy on heredity, by far the most difficult and important of all those subjects which at present attract the attention of the biologist; but an attack of illness has compelled me to abandon my purpose. Not that I proposed to venture to express any opinions of my own, for, with such protagonists in the field as Weismann, Wallace, Romanes, and Poulton on the one side, and Herbert Spencer and Hartog on the other, '*Non nostrum inter vos tantas componere lites.*'

So far as I can understand Weismann's theory, he assumes the separation of germ cells and somatic cells, and that each germ cell contains in its nucleus a number of 'ids,' each 'id' representing the personality of an ancestral member of the species, or of an antecedent species. 'The first multicellular organism was probably a cluster of similar cells, but these units soon lost their original homogeneity. As the result of mere relative position, some of the cells were especially fitted to provide for the nutrition of the colony, while others undertook the work of reproduction.' The latter, or germ-plasm, he assumes to possess an unlimited power of continuance, and that life is endowed with a fixed duration, not because it is contrary to its nature to be unlimited, but because the unlimited existence of individuals would be a luxury without any corresponding advantage.

Herbert Spencer remarks upon this: 'The changes of every aggregate, no matter of what kind, inevitably end in a state of equilibrium. Suns and planets die, as well as organisms.' But has the theory been proved, either by the histologist, the microscopist, or the chemist? Spencer presses the point that the immortality of the protozoa has not been proved. And, after all, when Weismann makes the continuity of the germ-plasm the foundation of a theory of heredity, he is building upon a pure hypothesis.

From the continuity of the germ-plasm, and its relative segregation from the body at large, save with respect to nutrition, he deduces, *à priori*, the impossibility

of characters acquired by the body being transmitted through the germ-plasm to the offspring. From this he implies that where we find no intelligible mechanism to convey an imprint from the body to the germ, there no imprint can be conveyed. Romanes has brought forward many instances which seem to contradict this theory, and Herbert Spencer remarks that 'a recognised principle of reasoning—"the law of parsimony"—forbids the assumption of more causes than are needful for the explanation of phenomena. We have evident causes which arrest the cell multiplication, therefore it is illegitimate to ascribe this arrest to some property inherent in the cells.'

With regard to the reduction or disappearance of an organ, he states 'that when natural selection, either direct or reversed, is set aside, why the mere cessation of selection should cause decrease of an organ, irrespective of the direct effects of disease, I am unable to see. Beyond the production of changes in the size of parts, by the selection of fortuitously arising variation, I can see but one other cause for the production of them—the competition among the parts for nutriment. . . . The active parts are well supplied, while the inactive parts are ill supplied and dwindle, as does the arm of the Hindu fakir. This competition is the cause of economy of growth—this is the cause of decrease from disease.'

I may illustrate Mr. Herbert Spencer's remarks by the familiar instance of the pinions of the Kakapo (*Stringops*)—still remaining, but powerless for flight.

As for acquired habits, such as the modification of bird architecture by the same species under changed circumstances, how they can be better accounted for than by hereditary transmitted instinct, I do not see. I mean such cases as the ground-nesting *Didunculus* in Samoa having saved itself from extinction since the introduction of cats, by roosting and nesting in trees; or the extraordinary acquired habit of the black-cap in the Canaries, observed by Dr. Lowe, of piercing the calyx of *Hibiscus rosa-sinensis*—an introduced plant—to attract insects, for which he quietly sits waiting. So the lying low of a covey of partridges under an artificial kite would seem to be a transmitted instinct from a far-off ancestry not yet lost; for many generations of partridges, I fear, must have passed since the last kite hovered over the forefathers of an English partridge, save in very few parts of the island.

I cannot conclude without recalling that the past year has witnessed the severance of the last link with the pre-Darwinian naturalists in the death of Sir Richard Owen. Though never himself a field-worker, or the discoverer of a single animal living or extinct, his career extends over the whole history of palæontology. I say palæontology, for he was not a geologist in the sense of studying the order, succession, area, structure, and disturbance of strata. But he accumulated facts on the fossil remains that came to his hands, till he won the fame of being the greatest comparative anatomist of the age. To him we owe the building up of the skeletons of the giant *Dinornithidæ* and many other of the perished forms of the gigantic sloths, armadilloes, and mastodons of South America, Australia, and Europe. He was himself a colossal worker, and he never worked for popularity. He had lived and worked too long before the Victorian age to accept readily the doctrines which have revolutionised that science, though none has had a larger share in accumulating the facts, the combination of which of necessity produced that transformation. But, though he clung fondly to his old idea of the archetype, no man did more than Owen to explode the rival theories of both Wernerians and Huttonians, till the controversies of Plutonians and Neptunians come to us from the far past with as little to move our interest as the blue and green factions of Constantinople.

Nor can we forget that it is to Sir Richard's indomitable perseverance that we owe the magnificent palace which contains the national collections in Cromwell Road. For many years he fought the battle almost alone. His demand for a building of two stories, covering five acres, was denounced as audacious. The scheme was pronounced foolish, crazy, and extravagant; but, after twenty years' struggle, he was victorious, and in 1872 the Act was passed which gave not five, but more than seven acres for the purpose. Owen retired from its direction in 1883, having achieved the crowning victory of his life. Looking back in his old age on the

scientific achievements of the past, he fully recognised the prospects of still further advances, and observed, 'The known is very small compared with the knowable, and we may trust in the Author of all truth, who, I think, will not let that truth remain for ever hidden.'

I have endeavoured to show that there is still room for all workers, that the naturalist has his place, though the morphologist and the physiologist have rightly come into far greater prominence, and we need not yet abandon the field-glass and the lens for the microscope and the scalpel. The studies of the laboratory still leave room for the observations of the field. The investigation of muscles, the analysis of brain tissue, the research into the chemical properties of pigment, have not rendered worthless the study and observation of life and habits. As you cannot diagnose the Red Indian and the Anglo-Saxon by a comparison of their respective skeletons or researches into their muscular structure, but require to know the habits, the language, the modes of thought of each; so the mammal, the bird, and even the invertebrate, has his character, his voice, his impulses, aye, I will add, his ideas, to be taken into account in order to discriminate him. There is something beyond matter in life, even in its lowest forms. I may quote on this the caution uttered by a predecessor of mine in this chair (Professor Milnes Marshall): 'One thing above all is apparent, that embryologists must not work single-handed; must not be satisfied with an acquaintance, however exact, with animals from the side of development only; for embryos have this in common with maps, that too close and too exclusive a study of them is apt to disturb a man's reasoning power.'

The ancient Greek philosopher gives us a threefold division of the intellectual faculties—*φρόνησις, ἐπιστήμη, σύνεσις*—and I think we may apply it to the subdivision of labour in natural science: *φρόνησις, ἡ τὰ καθ' ἕκαστα γνωρίζουσα*, is the power that divides, discerns, distinguishes—*i.e.*, the naturalist; *σύνεσις*, the operation of the closet zoologist, who investigates and experiments; and *ἐπιστήμη*, the faculty of the philosopher, who draws his conclusions from facts and observations.

The older naturalists lost much from lack of the records of previous observations; their difficulties were not ours, but they went to nature for their teachings rather than to books. Now we find it hard to avoid being smothered with the literature of the subject, and being choked with the dust of libraries. The danger against which Professor Marshall warns the embryologist is not confined to him alone; the observer of facts is equally exposed to it, and he must beware of the danger, else he may become a mere materialist. The poetic, the imaginative, the emotional, the spiritual, all go to make up the man; and if one of these is missing, he is incomplete.

I cannot but feel that the danger of this concentration upon one side only of nature is painfully illustrated in the life of our great master, Darwin. In his early days he was a lover of literature, he delighted in Shakespeare and other poets; but after years of scientific activity and interest, he found on taking them up again that he had not only grown indifferent to them, but that they were even distasteful to him. He had suffered a sort of atrophy on that side of his nature, as the disused pinions of the Kakapo have become powerless—the spiritual, the imaginative, the emotional, we may call it.

The case of Darwin illustrates a law—a principle we may call it—namely, that the spiritual faculty lives or dies by exercise or the want of it even as does the bodily. Yet the atrophy was unconscious. Far was it from Darwin to ignore or depreciate studies not his own. He has shown us this when he prefixed to the title-page of his great work the following extract from Lord Chancellor Bacon:—'To conclude, therefore, let no man, out of a weak conceit of sobriety, or an ill-applied moderation, think or maintain that a man can search too far, or be too well studied in the book of God's word, or in the book of God's works, divinity or philosophy, but rather let men endeavour an endless progress or proficience in both.' In true harmony is this with the spirit of the father of natural history, concluding with the words, 'O Lord, how manifold are Thy works! in wisdom hast Thou made them all: the earth is full of Thy riches.'

FRIDAY, SEPTEMBER 15.

The following Papers and Report were read:—

1. *On the Physico-chemical and Vitalistic Theories of Life.* *By* J. S. Haldane.

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2. *On the Effect of the Stimulation of the Vagus Nerve on the Disengagement of Gases in the Swimming-bladder of Fishes.* *By* Dr. Christian Bohr.

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3. *On Malformation from Pre-natal Influence on the Mother.* *By* Alfred R. Wallace, *D.C.L., F.R.S.*

In a letter to 'Nature' (August 24) on 'Pre-natal Influences on Character,' I stated—rather hastily, as it now appears—that physiologists rejected the notion of physical peculiarities being thus caused, both on account of the total absence of trustworthy evidence and also on theoretical grounds. In the article 'Deformities' in the new edition of 'Chambers's Encyclopædia' (by Professor A. Hare) I find the following statement:—'In an increasing proportion of cases which are carefully investigated it appears that maternal impressions, the result of shock or unpleasant experiences, may have a considerable influence in producing deformities in the offspring. This has long been a popular theory, and it is one that recent scientific observation is tending to confirm.'

In consequence of my letter in 'Nature' several alleged cases of the kind above referred to have been sent me, one of which, being illustrated by a photograph and attested by a perfectly competent observer, will, I think, interest all biologists. The account was sent me by Dr. Richard Budd, M.D., F.R.C.P., Physician to the North Devon Infirmary. The following is a copy of his statement:—

'In the year 1861 a gamekeeper named Croucher was admitted to the North Devon Infirmary in consequence of a gunshot wound of the right forearm. The arm was amputated just below the elbow. Croucher left the infirmary before the wound was quite healed, in the belief that his wife would be able to dress it. In this he was mistaken; but a young woman, the wife of a neighbouring farmer, volunteered her services, and continued to dress the wound till it was healed. Some six or seven months after this young woman was confined, and her child was born minus the right forearm, and the stump was a facsimile of Croucher's. The gamekeeper's arm became somewhat wasted by the pressure induced by an artificial arm, and therefore the resemblance of the two arms (in the photograph taken some years later) is not so exact as it was at first. The photographs were taken by me.

'(Signed) Richard Budd, M.D., F.R.C.P.,
'Physician to the North Devon Infirmary.

'Barnstaple: September 4, 1893.'

In a letter Dr. Budd adds: 'With regard to the Croucher case, I am not aware that the facts have been published in any of the medical periodicals, but I exhibited and explained the photographs at a grand meeting at the College of Physicians (in November 1876), when most of the celebrated physicians of the world were present, and they created the deepest interest.'

I presume that the birth of a child with an arm exactly resembling that in the photograph is an exceedingly rare occurrence in England, and that the probability of one being thus born in the *same place* where there was a man with a similar arm is exceedingly slight. When we add to this the further improbability of such a child being born within nine months after the accident, and the mother being the

particular woman who repeatedly dressed the wounded arm, it seems impossible to avoid accepting a causal connection between the two events.

Should such a connection be established, both on the physical and mental side, we have evidently a new cause of modification distinct from normal heredity. It has more analogy with the supposed inheritance of acquired variations, but is quite distinct from it. It seems not unlikely that some of the cases of supposed heredity of mutilations may be really due to this mental effect on the mother. It therefore becomes very important that the whole subject should be thoroughly investigated.

The following letter has also been received from Dr. Budd:—

'Barnstaple: September 10, 1893.

'My dear Sir,—Some years ago the late Sir Frederick Williams, Bart., sent a brood mare, that had just been covered by a thorough-bred stallion, from his seat in Cornwall, Tregullo, to his shooting-cottage at Heanton Puncharden, near Barnstaple. When the groom entered the stable the following morning he found that one of the mare's eyes was hanging by a nail in the wall. The mare was then placed for a run in the Braunton marshes. In due time she produced a foal minus an eye on the same side as the mare's. The year following this mare again had a foal with one eye; but the third year she had a foal with two good eyes, the impression on her brain having worn out. This, in my opinion, is quite as interesting a case as Croucher's.

'In great haste to save this post,

'Yours sincerely,

'RICHARD BUDD.'

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4. *On Calorimetry by Surface Thermometry and Hygrometry.* *By* AUGUSTUS D. WALLER, *M.D.*, *F.R.S.*

This is in continuation of a communication made at the Liège Congress of Physiology (1892). Of the conclusions then published the only one needing to be quoted for the present purpose is that *the alteration of temperature of a limb in consequence of the exercise of its muscles is mainly a vascular effect.* Which signifies that the measurements given below are of muscular and vascular phenomena, not of muscular phenomena alone.

To form an approximate estimate of the calorimetric value of surface thermometric readings I proceeded as follows: Readings were taken at intervals of an internal and of an external thermometer in connection with an indiarubber sphere of known surface, containing a known weight of warm water, allowed to cool in still air. Readings of a third thermometer gave the temperature of the air. The internal thermometer indicated the heat loss in calories; the external thermometer gave indications that were proportional with the temperature-difference (hereafter referred to as the T.D.) between the surface of the sphere and the surrounding air. In this way it was estimated that each degree of indicated T.D. signified a heat-emission of approximately 12·5 calories per 1,000 cm.^{2} per minute.

The T.D. observed on the naked forearm was, under ordinary conditions, found to be between 10° and 15° C. Assuming that, *cæteris paribus*, the radiation from the skin was equal to that from the indiarubber, and taking the superficial area of the forearm (not including the hand) at 500 cm.^{2}, the heat-emission within the above range of T.D. is 62·5 to 94 cals. per minute.

Theoretically there are two obvious weak links in this argument, but for practical purposes it may be acted upon; it affords a more tangible series of expressions for variations of heat-emission under various conditions than is afforded by merely thermometric terms, and the calorimetric values thus obtained possess at least an equal degree of accuracy with those obtained by partial calorimetry.

The weak links are (1) that Newton's law of cooling is not absolutely correct; (2) that the coefficient of radiation varies with the nature of the cooling surface.

1. *Newton's law is not absolutely correct;* the heat-emission by radiation and conduction per 1° T.D. is a diminishing value with diminishing T.D. We may

not therefore, strictly speaking, give the value of heat-emission as constant per degree T.D., nor make, as above, the assumption that cal. = T.D. $\times \kappa$. But the discrepancy is not very serious within a range of 5° or even of 10°, and it is easily eliminated. Thus we may treat the discharge at 10° T.D. as a constant, and give the variations per degree above this value. Or, better, we may draw up a table of the values T.D.$^{1\cdot233} \times \kappa$. The following table gives in three parallel columns the calorimetric values per minute per 1,000 cm.^{2} of temperature-differences such as are ordinarily observed on the human forearm; 1° on the least accurate assumption cal. = T.D. $\times \kappa$; 2° on the more accurate assumption cal. = C $\pm$ (T.D. − 10) κ; 3° on the least inaccurate assumption cal. = κ T.D.$^{1\cdot233}$. Variations of barometric pressure have been treated as negligible. Calories per minute per 1,000 cm.^{2}; or millicalories per minute per cm.^{2}:—

T.D.	Cal. = 12·5 T.D.	Cal. = 120 + 15(T.D. − 10)	Cal. = 7 T.D.$^{1\cdot233}$
15	187·5	195	197·50
14	175	180	181·24
13	162·5	165	165·42
12	150	150	149·88
11	137·5	135	134·63
10	125	120	119·70

2. *The coefficient of radiation varies with the nature of the radiating surface.*—Heat is emitted from a warm surface, such as the human skin, by conduction, by evaporation, and by radiation. We may not assume that loss by radiation is identical from the surface of the indiarubber sphere and from an equal area of human skin. Moreover, we must admit as theoretically possible that the radiating power of the skin, apart from alterations of temperature, may vary.

I have not attempted to determine what is the percentage of the total loss borne by radiation alone, nor the variations of that percentage with varying character of surface. I have (1) taken simultaneous and separate estimates of the loss (*a*) by evaporation, (*b*) by conduction and radiation conjoined; (2) made experiments to see whether the loss by radiation *cum* conduction was sensibly altered by gross differences of the radiant surface; (3) compared roughly by thermopile and galvanometer the radiation of a warm indiarubber surface with that of the human skin; and (4) tried whether radiation from the human skin varied parallel with variations of T.D., or in such wise as to suggest the intervention of a distorting factor, such as an alteration of the radiating power.

All these were comparatively rough experiments, made not to determine actual alterations of heat-emission with alterations of radiant power, but to determine whether the latter could be regarded as markedly influencing the result, and thus forbidding the translation of surface thermometer readings of T.D. into calorimetric values of heat-emission.

I found (1) that two otherwise similar spheres with respectively white and black covers showed no difference in the rate of cooling outside the range of experimental error, apart from variations due to differences of T.D., or of thickness of cover, or of moisture of cover, or of air; (2) that practically the amount of radiation was proportional to the T.D., within a range of variation of 10° C.; (3) that the radiant power of the indiarubber surface did not sensibly differ from that of the skin of the forearm, with identical values of the T.D.

From which I concluded (1) that variations of radiant power are negligible in observations of this order;[1] (2) that the absolute calorimetric standard obtained from observations on the cooling sphere of water might without gross error be applied to the heat-emission of the human skin.

3. *The evaporation factor in heat-emission has to be separately dealt with.*—To

[1] Dr. Stewart, in the course of experiments on the radiation from the animal body (*Studies from the Physiological Laboratory of Owens College, Manchester*, 1891), has anticipated me in this first conclusion, to the effect that heat-emission depends upon the T.D. and not upon variations of radiating power.

this end I used a simple hygrometer, consisting of a shallow glass capsule, in the flat bottom of which some calcium chloride solution had been evaporated to dryness. The amount of water vapour discharged was ascertained by weighing the capsule before and after it had been left inverted for a given period over the skin or other surface of evaporation; the corresponding quantity of heat emitted was taken as equal to the weight of water × by the latent heat of evaporation. By preliminary trials it was found that the water discharge varied from 2 to 20 mgrms. per 20 cm.^{2} per 10 min. at various parts of the skin under ordinary varying conditions, and that a capsule inverted over a wet surface can absorb between 80 and 90 mgrms. per 20 cm.^{2} per 10 min.[1] It was also found by trial on a wet cooling sphere that the amount of heat ascertained by means of the internal thermometer to be lost was approximately found by calculations from the data furnished by the external thermometer and the hygrometer conjointly. Thus, *e.g.*, against a loss of 400 cals. per min. indicated by the internal thermometer there were found 150 cals. by the surface thermometer (the T.D. being 12°, and taking out from the calorimetric values tabulated above the corresponding number) *plus* 240 to 270 cals. by the evaporation of 400 to 450 milligrammes of water.

Assuming that the graduation is not grossly inaccurate, and that the argument upon which it rests is not grossly incorrect, the following numbers represent the state of heat-emission from a human forearm, with a superficial area of 500 cm.^{2}, (*a*) during rest after rest, (*b*) during rest after previous moderate exertion. The air temperature during experiment was 20°.

	After Rest	After Exertion
T.D.	12°	14°
I.e. heat-emission in cals. per min. . .	75	90
Water-emission in grammes per 20 cm.^{2} per 10 min.	0·004	0·030
I.e. heat-emission in cals. per min. . .	6	45
Total heat-emission in cals. per. min. .	81	135

In carrying out investigations of this character, it is of great advantage to employ the graphic method. Amount and rhythm of muscular exercise are recorded by a dynamograph, as described in my 'Introduction to Human Physiology'; surface-temperature by an air-thermograph, the essential part of which is a thin metal box strapped to the limb, and connected with a piston-recorder in contact with a slowly revolving cylinder, as will be described in a future communication; the area of the thermographic curve thus recorded represents a calorimetric value, and its ordinate a rate of heat-emission.

The method is easily carried out; the surface thermometer (or thermograph) and the calcium chloride hygrometer are well adapted to the clinical investigation of the heat and water emission of the skin under various pathological conditions.

5. *On a Method of Recording the Heart Sounds.* *By* Professor W. Einthoven.

6. *On Nerve Stimulation.* *By* F. Gotch, *F.R.S.*

7. *On the Digestive Ferments of a large Protozoon.* *By* Marcus Hartog *and* Augustus E. Dixon.

The authors have experimented with *Pelomyxa palustris*, of which the largest individuals attain a diameter up to 2 or even 3 millimetres ($\frac{1}{12}$–$\frac{1}{8}$ inch).

This organism, which is a gigantic multi-nucleate amœba, is found in abundance in the mud at the bottom of a small concrete tank at Queen's College, Cork. After

[1] Details will be given in a further communication dealing with cutaneous secretion.

collecting the mud and levigating off the fine silt, the organisms are collected by sucking them up from among the coarser *débris,* treated with 95 per cent. spirit, picked out singly with a mounted needle from the *débris* which had necessarily been sucked up with them, dried over oil of vitriol, and pounded. The impalpable powder (moistened with alcohol, as water wets it with difficulty) is extracted with water.

The watery extract shows the following properties :—

1. It hydrolyses starch paste in a neutral solution, but much less readily in presence of dilute mineral acids. It converts the starch rapidly into erythro-dextrin, but the formation of a sugar which will reduce alkaline copper solution is somewhat tardy.
2. It has no action whatever on thymolised milk in two days.
3. It liquefies fibrin rapidly in presence of dilute acids, but it is only after prolonged action that a distinct biuret reaction reveals the presence of pepsin.
4. It only attacks fibrin very slowly, and partially in neutral solution, and indol and skatol are not formed.

The enzymes present, therefore, resemble *ptyalin* and *pepsin; trypsin, rennin,* and *steapsin* (or *pialyn*) appear to be absent.

About 1,000 individuals furnish one grain of dry substance. Two series of experiments were made with about this quantity of material each time. It is proposed to repeat and complete the research in the autumn.

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8. *Report on the Physiological Action of the Inhalation of Oxygen.*

See Reports, p. 551.

Department of Zoology.

1. *On the Luminous Organs of Cephalopoda.* By William E. Hoyle.

It was recorded by Vérany so long ago as 1851 that certain spots on the body and arms of the rare and beautiful cuttlefish (*Histioteuthis Bonelliana*) gave out a phosphorescent light in the dark, but no subsequent observer has been fortunate enough to have the opportunity of confirming his observation, or indeed of procuring a specimen of the species. The allied form (*Histioteuthis Rüppellii*), which has spots of precisely similar appearance, has been several times examined, though never in the living condition. During the early part of the present year Professor Joubin, of Rennes, published an account of his examination of the structure of these organs. My own investigations have been made upon *Histioteuthis Rüppellii*, upon another rare species, *Calliteuthis reversa*, and upon two species of *Enoploteuthis*, a genus remarkable for having a number of the suckers developed into formidable hooks.

As regards the first, the specimen at my disposal was not in a very satisfactory state of preservation, so that I can say no more than that my results on the whole agree with those of Joubin.

In *Calliteuthis*, a genus not far removed systematically from *Histioteuthis*, the organs are essentially similar in distribution and in appearance to the naked eye, and, as might therefore be expected, they are very similar in structure. The most noticeable differences are that the distinction between the lens and the transparent cone of Joubin is scarcely marked, and that the mirror situated anteriorly to the main part of the organ is scarcely marked. These points may, however, be due to the sections having been made from a very young specimen.

In *Enoploteuthis* the appearance and structure of the organ are very different. When the surface of the body is examined under a pocket-lens there are seen among the ordinary chromatophores larger round spots, each having a pearly centre surrounded by a ring of pigment, and usually somewhat raised above the general level of the epithelium. These spots are confined to the ventral aspect of the animal, but are found on the mantle, funnel and arms, as well as round the eyes.

In one species I found three or four isolated ones in the centre of the dorsal surface of each fin.

In section it is seen that each organ is a spheroidal body embedded in the subcutaneous cellular tissue, and consisting of the following parts: (1) an outer pigmented cup with a considerable aperture (a quarter of its circumference) in front. (2) A lining within the cup, consisting of a single layer of cuboidal cells, with spherical nuclei, easily stained. (3) The anterior aperture of the pigment cup is filled by a lenticular body, composed of masses of a structureless yellowish material, to all appearance cuticular in nature, with small deeply-stained cells between the masses. (4) From the back of the lens there projects into the centre of the organ a conical plug, composed of deeply-stained cells. These are seen in transverse sections to be disposed concentrically round the axis of the cone, producing the effect of the well-known 'cell nests' of an epithelioma. (5) The space between this plug and the cells lining the pigment cup is filled with a clear transparent mass. In its peripheral portions this seems to be made up of thin layers arranged concentrically like the coats of an onion; whilst nearer the centre it has the form of curved rods, wider in front than behind, amongst which nuclei are sparsely scattered.

In most cases a space, most likely a blood lacuna, was seen around the organ; no nerve supply could be traced out.

It is impossible without an opportunity of examining the living animal to say what part of this apparatus is the active agent in producing the light; indeed, it must be remembered that positive proof of its being a luminous organ at all is still wanting.

Of similar structures as yet described in other animals it seems to resemble most nearly the photospheria of *Nyctiphanes norvegica*, a schizopod crustacean examined by Messrs. Vallentine and Cunningham. As regards origin, these organs are probably to be regarded as highly modified chromatophores; an analogous modification would be found in the thermoscopic spots recently described by Joubin in another cephalopod.

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2. *Report on the Marine Zoology of the Irish Sea.*—See Reports, p. 526.

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3. *Interim Report on a Deep-sea Tow-net.*

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4. *The Origin of Organic Colour.* *By* F. T. Mott, *F.R.G.S.*

In a complete plant of the higher orders there are three distinct schemes of colour—viz., the browns, olives, and maroons of the stem and branches, the greens of the foliage, and the reds, yellows, and blues of the blossom.

These indicate a successive decrease in the amount of light absorbed, which must be the result of changes in the absorbing capacity of the molecules. It is suggested that the cause of these changes may be found in the specially organic phenomenon of food assimilation, and the concentration of energy in the molecular structure which this implies. If such energy is stored in the form of increased molecular vibration, sets of molecules will successively reach the maximum limit of vibration possible to them, and will lose the power of further absorption. Thus the amount of reflected light will increase as the plant attains maturity; and as the arrest of growth which accompanies the formation of blossom throws upon the vibration of the molecules the energy otherwise expended upon growth, a marked increase of reflected light from the flower is the natural result.

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5. *Remarks on the Roots of the Lemna and the Reversing of the Fronds in* Lemna trisulca. *By* Nina F. Layard.

The roots of the various English Lemnæ are usually described as identical in form and structure, if, indeed, they receive any attention at all; but a careful

comparison of their forms will show certain distinct, albeit slight, differences, sufficiently marked to make it possible to identify a plant by means of the root alone.

One of the objects of this paper was to point out those differences by means of diagrams in which the respective roots of *Lemna minor, trisulca, gibba,* and *polyrhiza* were represented side by side.

Besides a considerable variety in the length of the various root-fibres, a microscopic examination of the sheaths which protect the apex shows that neither are they uniform in shape, but, ranging from the comparatively blunt and straight ampulla of *Lemna minor* to the slightly pointed sheath of *Lemna gibba,* they become blade-like in *Lemna polyrhiza,* and, finally, sharply pointed and with a tendency to curve in *Lemna trisulca.*

As the plant matures the sheath becomes a ruddy brown colour, and is seen under the microscope to be freckled with brown blotches, probably the decaying outer cells of the case. This hardening of the ampulla is a very necessary security against the attacks of water insects, which feed upon the delicate root fibres, often commencing at the extremity of the root and working their way upwards.

It is interesting to speculate as to possible other uses for this rather phenomenal root-cap. The functions of the root-caps of terrestrial plants are easily recognised in their adaptability to the purpose of forcing a way for the fibre through soil or pebbles, but here we have plants suspended in the water, and yet furnished with something very similar. This difficulty has been met by the suggestion that the sheath of the Lemna is not a root-cap, but really a persistent digestive pouch; but, even without this explanation, one has only to take into consideration the characteristics of the habitat of the duckweed to see that the ampulla is continually required to do the work of any ordinary root-cap of terrestrial plants. Owing to the stagnant nature of the ponds and dykes where it flourishes the plant is subjected to violent alternations of drought and plenty, and in the dry season myriads of perishing Lemnæ are left high and dry on the banks. The more fortunate individuals, growing where the water is deeper, are gradually let down as it becomes more shallow, until at last, striking their roots on the soil at the bottom, they are embedded in the mire, and there await the return of rain.

A curious hooked appearance which is occasionally seen in the ampulla of *Lemna trisulca* was also represented in the diagrams.

In the long chains formed by a number of connected fronds of *Lemna trisulca* it will not infrequently be found that the root-fibres spring sometimes from below the frond and hang downwards, and sometimes from what appears to be the surface of the frond, reaching upwards. A careful observation of the tendency of this submerged duckweed under certain circumstances to twist into an almost spiral form led the author to the conclusion that in such cases the fronds had completely revolved in their sockets, so that what had at first been underneath was now uppermost, throwing the root attached to it up to the surface. Further observations seemed to point to the fact that this habit is confined to cases where the submerged *Lemna trisulca* is covered from light and air by a thick overgrowth of other weeds, such as *Lemna minor,* with which it is often associated; for in a pond where this was not the case the uncovered chains of *Lemna trisulca* were lying almost flat, but after being placed in a basin already containing *Lemna minor* they also assumed an irregular spiral form in the course of a few weeks. Should this change be found to be attributable to a want of air it may possibly point to a respiratory function in the root-fibre.

SATURDAY, SEPTEMBER 16.

The following Reports and Papers were read:—

1. *Interim Report on the Botanical Laboratory at Peradeniya, Ceylon.*

2. *Interim Report on the Legislative Protection of Wild Birds' Eggs.* See Reports, p. 552.

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3. *On the Ætiology and Life-history of some Vegetal Galls and their Inhabitants.*[1] *By* G. B. ROTHERA.

In the restricted sense in which the term is here applied, galls are defined as complex organisms resulting from the co-operation of a plant and an animal; and to determine the extent and *modus operandi* of these two factors in their production is one of the many interesting problems which this study presents. Though abnormal with regard to the plant, inasmuch as their presence is exceptional and foreign to the performance of its proper functions, galls are in themselves as normal as any other organisms. Each has its own characteristic form, its special habitat, and its proper office. Hence, after referring to the great diversity of these organisms and their wide distribution, the writer proceeds to trace out the life-history of certain typical galls, those of *Cynips Kollari*, *Teras terminalis*, and *Biorhiza aptera* being specially dealt with.

What is there, he asks, in the casual presence of the ovum of the gall-producing insect, in the action of the developing larva, in the mechanical puncture of the parent cynips, or in the deposit of a tiny drop of irritating fluid by which it is said the ovipositing is accompanied—what is there in any one, or more, or all of these, or, it may be, in the action of some other factor yet to be discovered, that impels these wonder-working changes by which the gall itself is initiated and its future growth and development accompanied? Reviewing the various attempts made to answer this and cognate questions, as also the arguments by which the generally accepted view of the deposit by the parent cynips of a special virus is supported, the author denies the alleged analogy upon which the conclusion thence arrived at rests. The presence of the ovum (not found in any of the cases stated) may be, he suggests, as necessary a factor in the production of the gall as is the deposit of a specific virus; while in many cases galls are found to result from the action of other animals than terebrant hymenoptera—as, for example, of kermes, cecydomiæ, and acari—where no such poison-gland as that referred to exists. Very early in his investigations (now extending over a period of five-and-twenty years) the writer arrived at the conclusion that another agent, as potent as that of this hypothetical virus, was essential to the production of, at least, some species of vegetal galls, such agent being the presence and action of a living larva. In illustration of this the 'oak-apple' may be taken. Here the parent cynips (*Biorhiza aptera*—the agamic form of *Terasterminalis*), by a dexterous use of her terebra preparatory to ovipositing, makes a cut across the axis of a winter bud of the oak, above the circlet of scales by which it is surrounded, so as to separate the cone-like apex with its appendages. In the space thus prepared a variable number of eggs is laid—at times as many as two hundred and fifty or more. Should these, however, notwithstanding the incision, fail to be deposited, or, if laid, perish during the winter, no growth, normal or abnormal, takes place from the divided axis. This remains brown, dry, and inactive. If, on the other hand, healthy ova are present, and these hatch out their living embryos, then, by the action of these upon the dormant tissues, new and peculiar powers of growth are manifested—powers which result in the production, not of a normal branch, but of an abnormal, tumour-like gall. Here, then, we have a series of facts, positive and negative, which point to the action of the embryo, and not to the deposit of a special virus by the parent cynips, as the direct and necessary agent in the production of the gall. Granting, for the sake of illustration, the existence and potency of such virus, ought we not in such case to expect that, even in the absence of living larvæ, the normal energies of the fluid would be exerted, and a gall, destitute though it might be of normal occupants, of necessity result? In the author's long experience no facts confirmatory of this view have been met with, nor is it probable that any such barren galls exist. Are we not, then, justified in discarding the hypothesis of

[1] Published *in extenso* in *Natural Science*, November 1893.

a specific virus deposited by the parent cynips, and in attributing to the activities of the living embryos, combined with the normal forces of the plant, the genesis and metamorphoses of the gall?

This view has since been emphasised by Dr. Beyerinck, of Utrecht, who, as a deduction from the same facts, holds that in the action of the cynipidæ larvæ, and not in the injection of a specific virus by the parent cynips, the cause of gall formation is solely to be found. Whether so or not, however, this, at least, may safely be concluded, namely, that while, on the one hand, in those chemical and other forces which produce growth greater activity is induced by the stimulus of the injected fluid—assuming this to be actually present—so, on the other, those mechanical conditions which determine form in organic beings are furnished to a large extent by the contact of the included ovum and by the activities of the embryonic larva.

Resting in this solution of the problem, the author proceeds to deal with the facts of parthenogenesis and metagenesis, as exhibited in the gall-producing cynipidæ, and then to trace the operations of phytophagous and entomophagous inquilines and parasites,

'The unbidden crew of graceless guests' (*Virgil*),

which, season by season, decimate the cynips' larvæ, the legitimate possessors of the gall, living on their fatty juices, or so robbing them of their food that they die of poverty and inanition. But here, again, as if to punish wrong and work retributive justice, these inquiline and parasitic enemies in turn are preyed upon by other parasites lower in the scale of creation than themselves, which thin their ranks, and thus, in a rude and barbarous way, maintain the necessary balance of organic life.

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4. *On some New Features in Nuclear Division in* Lilium martagon. *By* Professor J. B. Farmer.

A careful examination of the course of development of the pollen in *Lilium martagon* shows the presence of a varying number of bodies which seem to have escaped the observation of those who have hitherto investigated this plant. To these bodies the general term 'granule' has been given, as one which involves no assumption as to their real nature. These granules are not easily made clear except by the careful use of selective stains. One of the best methods, though by no means the only one, of sharply differentiating them is that of double staining with hæmatoxylin and orange G. The great importance of the granules lies in the fact that a variable number of them may become converging points for the achromatic spindle fibres, and the whole spindle thus becomes multipolar and *irregular*. This does not, at any rate in the earlier stages of karyokinesis, terminate in any definite granule which may be regarded as a 'centrosome.' This behaviour on the part of the granules obviously affects deeply the whole question of the individuality of the centrosome.

As to the origin of the granules, it is of extreme interest to find that they appear suddenly in the cytoplasm, which had hitherto been perfectly free from them. Their appearance is immediately subsequent to the fragmentation of the large nucleolus during the preparatory stages of division, and moreover in their staining reactions they exactly coincide with those presented by this structure. A possible connection between the nucleolus and the granules is thus indicated.

During the later period of division the granules become fewer and larger, but their ultimate fate is not as yet quite clear.

The above points were illustrated by photomicrographs.

MONDAY, SEPTEMBER 18.

The following Papers and Reports were read :—

1. *On Coral Reefs. By* W. J. SOLLAS, *M.A., F.R.S.*

A discussion on Coral Reefs was opened by the reading of this Paper.

2. *Report on Work carried on at the Zoological Station, Naples.*

See Reports, p. 537.

3. *Report on Work carried on at the Biological Station, Plymouth.*

See Reports, p. 546.

4. *Interim Report on the Index Generum et Specierum Animalium.*

See Reports, p. 553.

5. *A few Notes on Seals and Whales seen during the Voyage to the Antarctic, 1892–93. By* WM. S. BRUCE.

During the recent Antarctic cruise at least three kinds of seals were seen. These were all true seals; no fur seals were seen. They were the sea-leopard (*Stenorhynchus leptonyx*), Weddell's false sea-leopard (*Leptonyx Weddellii*), and a creamy-white seal, probably the crab-eating seal (*Lobodon carcinophaga*). There were two others, which were possibly younger forms of sea-leopard and crab-eating seals respectively. The latter, instead of being white, was mottled pale grey, but similar in form and size to, and often found among, the white seals. In December all the seals were in very bad condition, thinly blubbered and grievously scarred. The females were scarred as freely as the males. There was no marked preponderance in the number of the females. During January their condition improved, and by February they were heavily blubbered and free from scars. Loving the sun, they lie on the pack ice all day digesting their meal of the previous night, which consists chiefly of fish or small crustaceans, or both; the penguin is also occasionally their victim, and I have found stones in their stomachs.

By February the embryo is well developed, gestation probably beginning in December. It is extremely regrettable that it was during this period the indiscriminate slaughter took place, almost all the females towards the end of January and February being with young.

All the seals were found on the pack ice; the sea-leopard was on the outermost streams, and was most frequently to be found singly, though two or three might be on one piece of ice, but seldom more. Weddell's false sea-leopard was very rare, only four of them having been seen. The creamy-white seal and the pale mottled grey were in greatest abundance: these are found in fours, fives, or even tens—the greatest number I have seen on one piece was forty-seven. On one occasion we found some seals on a tilted berg; so high was the ledge above the water-level that our men with difficulty clambered up and secured their prey. This illustrates their great power of jumping from the water on to the ice. I have seen them rising about 9 feet above water, and cover distances of fully 20 feet in length.

It is of interest to note that we saw no trace of any whale resembling the bowhead or Greenland black whale (*Balæna mysticetus*) which Ross reported to have seen in very great numbers. There were, however, hunchbacks, finbacks, bottlenoses, and grampuses.

6. *On the Penguins of the Antarctic Ocean. By* C. W. DONALD, *M.B.*

The penguin is one of the most interesting of living birds. Its shape, erect posture, rigid flippers, its feathers, anatomy, and habits are all characteristic. The most common form in this region is the black-throated species—*Dasyrhamphus adelias* (H. & J.). A large rookery of this species, situated on the south shore of Joinville Island, was visited. On one occasion they were seen in large schools, each directed by an individual of larger species—probably an Emperor. On the ice he usually progresses in the erect posture. In the water he generally proceeds like a porpoise—in a prolonged dive broken at intervals of about thirty yards as he rises for breath—leaping clean out of the water, and immediately disappearing with scarcely a ripple, after clearing a space of two to two and a half feet. Experimenting on them, one was found to survive being held under water for six minutes. Their food consists chiefly of a large shrimp-like crustacean of the genus *Euphausia.* Their stomachs generally contain a number of angular pebbles. Large flocks of a white-throated penguin of the type described as *D. Herculis* (Finsch) were seen in February. I am of opinion that these are the young of *D. adeliæ.* The Emperor Penguin—*Aptenodytes Fosteri*—was met with on several occasions. One of these—of great size and beautiful plumage—was 4 feet 10 inches from tip of beak to extremity of tail. It weighed 74 lb. One specimen of the Kinged Penguin —*Pygosculis antarctica*—was obtained. A rookery occupied by the white-headed penguin—*Pygosculis papua*—was visited. The nests here were lined by feathers from the parents' breasts. I saw no crested penguins nor any specimen of the King—*Aptenodytes longirostris.* What I believe to be a new species of crested penguin was seen on the S. Orkneys by Captain Sarsen.

7. *On the Development of the Molar Teeth of the Elephant, with Remarks on Dental Series. By* Professor J. CLELAND, *F.R.S.*

A specimen was exhibited from the lower jaw of an Indian elephant of a molar tooth enclosed in its sac, and consisting of a series of seventeen transverse laminæ, each surmounted by comparatively elongated cusps. As yet only the cusps of the hindermost lamina were covered with caps of dentine, and the laminæ were separated one from another by projections of the saccular wall. It was pointed out that the cusps became afterwards less distinct by the growth of enamel taking place on the surface, and that the laminæ by remaining uncovered with dentine for a considerable period were enabled to enlarge to three or four times the breadth that they exhibited in the specimen. The elephant's molars may be said to be doubly compound; the cusps, originally separate, being united by the laminæ on which they are placed, and the laminæ being joined together afterwards by a common base on which the dentine is at a later period continued down, to be prolonged finally into fangs. It is doubtful if any hard distinction can be drawn between a transverse row of cusps conjoined together and a transverse series of separate teeth. Teeth ought to be recognised as occurring in the jaws in longitudinal and transverse series. The temporary and permanent teeth of mammals are in point of fact derived from papillæ forming respectively an outer and an inner range, while the additional teeth occurring occasionally in the human subject are instances of a third papilla being developed internal to the inner range; just as in sharks many teeth may lie in one transverse line. But this arrangement is disguised by each tooth being temporarily included in a sac, and has escaped notice.

The specimen has been presented to the British Museum.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *On Certain Gregarinidæ, and the possible connection of Allied Forms with Tissue Changes in Man. By* CHARLES H. CATTLE, *M.D., M.R.C.P., and* JAMES MILLAR, *M.D.*

After giving a general review of the classification of the protozoa, the writers pointed out that they were chiefly interested in the sporozoa, and that because of their parasitic habits, especially in the bodies of the higher vertebrates. There was much still unknown of the habits, life-history, and distribution of these organisms, and the co-operation of biologists with medical men was invited for the elucidation of many unsettled questions. One of these was how far certain of the sporozoa, at present classified as distinct species and genera, were to be properly so considered, and how far some of them were really alternative forms of the same organism modified by change of host and other external influences.

A detailed description was given of *the authors' own observations* on the development of the *coccidium oviforme* of the rabbit. On the authority of L. Pfeiffer [1] it was stated that in the body of its host, the coccidium multiplies by means of a most prolific zoöspore formation, while in external media it forms lasting spores. The authors took some material derived from the rabbit's gall-bladder, containing coccidia, and watched the development of the parasite under different external conditions. When the specimens were first observed, the granular protoplasm, contained in the coccidium capsule, had already contracted into a rounded mass, lying either in the centre, or somewhat to one end. The first specimen to show further change was one kept in ordinary water at the temperature of the air, and unsealed so that there was free access of air to it. Within a space of two days the granular ball had divided into two, and in some instances into four portions. Sometimes the final division was into three portions instead of four. As an ultimate result of the segmentation the parent coccidium came to contain three or four sporoblasts, each containing one or two (generally two) refractile translucent bodies (spores) and some granular matter, the so-called *nucléus de reliquat.* The authors entirely failed to see the C-shaped rod with thickened ends, which has been described [2] as lying within the sporoblasts. At a later stage individuals were met with in which the sporoblasts could be seen making their way out of the containing capsule and floating free in the surrounding fluid. The authors believe this is the first time this phenomenon has been actually observed; but they feel some doubt as to whether what they saw was entirely spontaneous, or had been assisted by the pressure of the cover-glass used in mounting the specimen on the slide. Probably under ordinary circumstances the spores remain unchanged for an indefinite time, and only undergo further change when they reach the interior of a new host. Ultimately they give origin to amœboid germs which penetrate into epithelial cells. The authors regard the interior of the tissue-cells as the necessary abode of the young forms of all sporozoa; and if this opinion is correct, they see great difficulties in the way of artificial cultivation of coccidia or any other true cell-parasite.

The tissue-changes in the rabbit's liver due to a known parasite (the coccidium) were stated to bear a close resemblance to those which constitute cancer in the human subject. In the latter bodies have of late years been described and which by many observers are considered as protozoa. The authors showed by means of lantern slides the structure of these latter bodies as they had found them in their preparations. The reasons for looking upon them as parasites were briefly—1. The cell-growth, which is the fundamental change in cancer, is quite analogous to the changes produced in animal tissues by known parasites. 2. They

[1] *Untersuchungen über den Krebs,* Jena, 1893.
[2] Leuckart, *The Parasites of Man,* 1886.

have a clearly defined outline and structure, which differ from those of tissue-cells and their nuclei; they are differently affected by stains. 3. Several observers, and among them one of the present authors (Dr. Cattle[1]), have published descriptions of what they consider to be a sporing process on the part of the 'parasite.' 4. They are found most abundantly where the disease is active and spreading; not where it has died out, and been replaced by scar-like connective tissue. 5. Drs. Ruffer and Soudakewitch report they have seen the parasite moving and dividing on the warm stage.

The authors concluded by expressing the opinion that by further observation and experiment, the protozoön of cancer might in time become an established fact. The Paper was illustrated by lantern slides.

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2. *On the Wings of* Archæopteryx *and of other Birds. By* C. Herbert Hurst.

The slender hind limbs, the small pelvis, the weak vertebral column made up of amphicœlous vertebræ, and the presence in the fore limb of long, slender, clawed fingers, admirably adapted for climbing in trees, justify the view that *Archæopteryx* was a quadruped using the free fingers of the fore limb much as the corresponding free fingers of the Pterosauria may have been used, and as the fingers of the 'flying' squirrels and phalangers, and of *Galeopithecus*, and as the thumbs of a bat, are undoubtedly used.

These three slender digits of the wing of *Archæopteryx* would, however, be useless for such a purpose if the seven large primary quills were attached to them as usually described, and the quills themselves would be useless if so attached; for the three slender fingers are far too weak, especially at the joints, to withstand the *torsional* stress to which they would be exposed in flight if the quills were attached to them. A single stroke of the wing would twist those fingers off at the joints. Such an attachment, indeed, would render both the fingers and the wings useless.

Comparison of the wing of *Archæopteryx* with the dissected wing of an ordinary bird suggests the position and size and form of bones which would be adequate to support the primary quills of *Archæopteryx*. Of these bones Owen figured two metacarpals and a very large carpal bone, and their equivalents have never been exposed in the Berlin specimen.

In the Berlin specimen, however, the presence of those bones is indicated, and they may even be made out in part in a photograph. The anterior (or preaxial) border of the wing from the carpal angle to the tip of the primary quills forms a bold curve which passes *under* the three slender fingers. A faint depression behind and parallel to the same fingers indicates roughly the hinder border of the group of bones and ligaments. The slender fingers not only do not contribute to the support of the wing, they do not even lie in the wing at all, but upon its feather-clad surface. The position of the three fingers and the numbers of phalanges (2, 3, and 4 respectively) which they possess show these to be the digits I., II., and III. of the normal pentadactyle limb, and there is hardly room for doubt that two fingers still lie buried in the Berlin slab—fingers which supported the primary quills, which were the equivalents of the two large digits partially exposed in the London specimen, and were also the homologues of the two large digits of an ordinary bird's wing. These were of course IV. and V., and therefore the two large digits of an ordinary bird's wing are IV. and V., and the 'ala spuria' is all that remains of the other three.

Well-known arguments against the descent of birds from pterodactyls rest upon the assumption that the two large digits are II. and III., and hence collapse if the interpretation above suggested be accepted.

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3. *On the Sensory Canal System of Fishes. By* Walter E. Collinge.

The importance of that system of sensory organs in fishes known as the sensory canal, lateral lines, &c., system has not yet been sufficiently estimated, and the

[1] *British Medical Journal*, July 1893.

absence of any recent systematic investigation has led me to give some attention to the same.

Its important bearing upon general morphology may be grouped under three headings:—

(i.) The important modifications that its presence has effected in the cranial and other bones of the skull.

(ii.) The modifications in the cranial nerves.

(iii.) The evidence of the evolution of a series of sensory organs.

My investigations have been chiefly carried out upon Ganoids, the more important results of which are summarised below.

In *Polypterus*:—

1. There is a complete absence of dendriform branches, and also of any openings corresponding to primitive pores. In these two features it agrees with the more highly specialised Ganoids.

2. The connection of the operculo-mandibular branch with the main canal is established contrary to the statements of Traquair, Allis, and Pollard, though not in the manner figured by Wiedersheim.

3. The presence of a canal traversing the series of lateral canal bones, and of another running across the cheek-plate, also a rudimentary one in the preoperculum.

4. The distinctness of the preoperculum hitherto considered as doubtful by both Huxley and Traquair.

In *Lepidosteus*:—

1. The presence of a system of dendritic branches which, passing off from the main canal, anastomose and form a dense network, which resembles in many points that found in the Selachia.

2. The absence of any branching on the lateral canal.

3. The presence of a preorbital commissure, not previously described as occurring in the Ganoids, and a prenasal commissure.

4. The distinctness of the preoperculum, termed by Parker interoperculum.

From further investigations, not yet completed, we may state that—

1. The canal system in the Elasmobranchs approaches in many points the condition found in the Selachoid Ganoids, both in the course of the canals, branches, sensory organs, &c., and in the branching of the lateral canal and in the distribution of the cranial nerves.

2. It seems very probable that the numerous sensory organs that have been described can be reduced to three or four, which are really only stages in the evolution of a sense-capsule.

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4. *On the Starch of the Chlorophyll-granule, and the Chemical Processes involved in its Dissolution and Translocation. By* HORACE T. BROWN, *F.R.S.*

Important advances have been made of late years in our knowledge of the carbohydrates and of the transformations which some of them undergo when they are acted upon by various enzymes or soluble ferments. The work described in this paper was an attempt by the author and his colleague, Dr. G. H. Morris, to apply the experience gained by a long acquaintance with the carbohydrates to the elucidation of some of the metabolic processes at work in green leaves.

They have been able to throw some new light upon the chemical and physiological processes involved in the formation of autochthonous starch, the first visible product of assimilation in the chloroplasts, have succeeded in explaining the mode of dissolution of this starch within the plant cell, and have demonstrated the nature of the wandering metabolites intermediate between the starch and the formation of new tissue. Full details of most of the results and of the methods employed will be found in the 'Journal of the Chemical Society,' 1893, p. 604. (See also 'Annals of Botany,' vol. vii. p. 271.)

It is possible to determine with great accuracy the starch of the chloroplasts of the leaf by converting it (after extraction of the ready-formed leaf-sugars) into

maltose and *dextrin* by hydrolysis with malt-diastase. The products of hydrolysis, when quantitatively determined by means of the polarimeter and by their cupric-reducing power, are a measure of the starch from which they are derived. In applying this method to a critical examination of the influence of surrounding conditions on the formation of leaf-starch, precautions have to be taken to arrest the vitality of the leaf at the moment of its separation from the plant.

The results of many varied experiments point consistently to the conclusion that starch is not an essential link in the chain of chemical products beginning with the inorganic materials, carbon dioxide and water, and ending with the form in which the assimilated material passes out of the leaf. No proof, direct or indirect, could be obtained of that rapid building up and breaking down of the starch which must be going on in every assimilating cell of starch-producing plants, if all the metabolites of a carbohydrate nature have to pass through the form of starch.

It appears almost certain that the deposition of starch within the chloroplast is governed by the same laws as those which regulate its deposition in the amyloplast of non-assimilating cells, and that this is primarily conditioned by the rate at which the soluble carbohydrates are supplied to the cell. Starch is only deposited in the chloroplasts or amyloplasts when the supply of this soluble material is greater than the local requirements of the individual cell, or its immediate powers of translocation.

When leaves are placed under conditions favourable for the depletion of their starch, the starch grains which are embedded in the chloroplast of the stomatic guard-cells are very much more stable than those of the palisade-cells or of the spongy parenchyma. This is due to the comparative physiological isolation of the guard-cells, an isolation brought about by the more or less complete cuticularisation of their walls, by their slight lateral attachment to the cells of the epidermis, and by the fact that they have no immediate connection with the mesophyll and the conducting sheaths surrounding the vascular bundles. The guard-cells, in fact, do not belong to the general republic of the assimilating cells of the parenchyma, but are autonomous. By the aid of their chloroplasts, which are always present, they assimilate only for themselves; and, on the other hand, when the conditions of illumination render assimilation no longer possible, the carbohydrate which they have stored up in the form of starch is only drawn upon for their own individual requirements, and is not passed into the stem, as are the products of dissolution of the starch formed in the parenchyma.

When it is considered how important it is to the plant that these guard-cells should be kept in a high state of working efficiency, and no matter what the variations in illumination may be, the advantages derived from the isolation and autonomous nature of these cells are very apparent.

A great number of experiments were made in order to determine the mechanism by which the starch is redissolved in the living cell of the leaf parenchyma, and rendered available for the requirements of the plant. It was found, notwithstanding the statements of Wortmann to the contrary, that leaves always contain far more diastase within their tissue than is necessary for the complete dissolution of the starch at any time present. A method was devised for the relative determination of the amount of this enzyme in the leaf, and the results of a great number of such determinations were given.

The leaves of the leguminosæ are pre-eminently rich in this enzyme, those of *Pisum sativum* having a diastatic activity equal to from one-half to one-third that of an average barley-malt.

The full diastatic effect of leaves is only apparent when the tissue, previously dried at a low temperature, is brought into actual contact with the starch solution. Mere infusions of the leaf are not very active, and if it contains any considerable amount of *tannin*, which is sometimes the case (*e.g.*, Hop, and *Hydrocharis morsus-ranæ*), the leaf infusion has no hydrolytic action at all on starch, owing to the enzyme having been prevented from going into solution by the tannin.

The products of the hydrolysis of starch under the action of leaf-diastase have been carefully studied, and are found to be identical with those formed under similar conditions by malt-diastase.

In a living plant, placed under favourable conditions, the starch of the chloroplasts disappears with much greater rapidity than it does if the leaf has been previously treated by some method which arrests the vitality of its cells, but does not affect the activity of the contained diastase. At first sight this fact, upon which Wortmann lays great stress, seems to negative the idea that the dissolution of the starch is due to hydrolysis by diastase. Recent experiments carried out by the author and his colleague have, however, convinced them that the action on the starch is really conditioned by the diastase, but that the action is enhanced and rendered continuous by the ability of the living elements of a cell to seize upon the chemical products of hydrolysis, and to remove them from the sphere of action by passing them into adjoining cells.

The amount of diastase present in leaf-cells is found to be subject to periodic fluctuations. Like the fluctuations in the amount of starch, those of diastase appear to be governed by the intensity of illumination. The conditions, however, which are favourable to a decrease of starch are just those which are favourable to an increase of diastase, and *vice versâ;* so that we find more diastase in a leaf during the night than during the day. This variation really appears to depend upon the rate of nutrition of the cells. Whilst these are supplied with an abundance of material in the form of freshly assimilated sugars they elaborate little or no diastase, but when the supply of these sugars falls off diastase is secreted for the purpose of dissolving the excess of carbohydrate which has been stored up as starch. The secretion of diastase by the leaf-cell, and, in fact, by every starch-containing cell, is a phenomenon of partial starvation, and is necessary for the autophagy of the cell. A precisely similar phenomenon had been previously observed during the germination of certain endospermous seeds.[1] This is a principle which will probably be found of general application to all cases of secretion of enzymes both by animal and vegetable organisms.

Certain experiments are then discussed which were planned with a view to ascertain the nature of the sugars existing in the leaf, their variations in amount at different periods, and the relation which each sugar bears on the one hand to the first product of assimilation, and on the other to the starch deposited within the chloroplasts. The leaves of *Tropæolum majus* were selected for this portion of the inquiry.

The only sugars which could be detected in any quantity were *cane-sugar, dextrose, levulose,* and *maltose.* Only mere traces of the pentoses could be found.

The results yielded by a study of the quantitative variations in the amount of the sugars and starch of leaves, when these have been placed under determinate conditions, are decidedly opposed to the view that either dextrose or levulose is the first sugar formed in the assimilative processes. *Cane-sugar* appears to be the first distinctly recognisable carbohydrate which is formed. There is every reason to believe that this cane-sugar, which may be regarded as the starting-point of all the metabolic changes taking place in the leaf, accumulates in the cell-sap of the leaf parenchyma when assimilation is proceeding vigorously. When the concentration passes beyond a certain point starch commences to be elaborated by the chloroplasts at the expense of the cane-sugar. This starch forms a more stable reserve substance than the cane-sugar itself, and is drawn upon when the more readily metabolised cane-sugar has been partially used up.

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5. *On Cytological Differences in Homologous Organs.* *By* Professor G. Gilson, *of Louvain.*

Remarkable differences may be detected in the minute structure of certain organs which are considered as unquestionably homologous; and it would not be without interest to know to what extent these differences may lead the morphologist to modify his views as to this homology.

A striking instance of such differences is found amongst the nephridia or segmental organs.

[1] *Cf.* Brown and Morris, *Jour. of Chem. Soc.*, 57 (1890), p. 458.

The nephridium of certain beings is an epithelial tube, the lumen of which owes its origin to the disjunction of the cells. This is the case with the vertebrate and other forms.

In other beings, as for instance the leeches, the organ is not really epithelial, if we give this word its original and etymological signification. It consists of an aggregation of cells with no disjunctive cavity whatever. All the lumina it possesses run through the body of the cells, and thus are *intra*cellular ductules, as Professor Lang was the first to remark long ago. In *Clepsine*, for instance, the whole organ consists of a single row of cells, with three separate canals running through it. These canals end in the upper part of this row of cells by spreading into a bunch of tiny ramifications creeping in the cytoplasm (fig. 1, *i.d.*).

In Hirudo the structure is a little more complicated by the fact that a sheath of cells surrounds the central canal. The cytoplasm of these cells contains a number of ramified ductules uniting from cell to cell, and opening at certain places into the central duct. The wall of this latter always shows in a transverse section, only as one single cell; that is to say, that its lumen is also an *intracellular* cavity.

It may be remarked that I do not take the usual diagrams of the nephridium as ordinarily given according to the observations of Bourne, Schultze, and others, but the somewhat different one lately given by Bolsius. I know that Bolsius's diagrams have been criticised by Mr. Bourne, of Madras. Nevertheless, I cannot help considering his views as much more nearly correct than those generally accepted. It is to be hoped that Bolsius will soon give some explanations about his disagreement from Mr. Bourne's descriptions.

Besides, be these diagrams accepted or not, we may remark that, whilst in vertebrates and other forms the nephridium is epithelial, and its lumen *intercellular*, *i.e.*, disjunctive, in the leeches, on the contrary, the organ is not epithelial, and its lumen is not disjunctive, but always *intracellular*.

It seems to me that differences of this character have a certain importance, at least for the evolutionist, for they imply corresponding differences in the processes of histogenesis.

The homology of the excretory organs of the different groups of animal forms is, indeed, still uncertain. We do not exactly know which are *homogenetic* and which simply *homoplastic*, to use two excellent terms proposed by Professor Ray Lankester. Every kind of information about them should be taken into consideration, and it is desirable that a minute cytological survey of the nephridia should be carried out through all groups.

But whatever may be the results of these investigations, I do not believe that such differences as those I have been speaking of could ever be regarded as a real objection against the homology, nor even against the homogeny, between the nephridia belonging to various animal groups.

If we admit, as I believe we must in the hypothesis of evolution, that the non-epithelial state was primary, there is no theoretical difficulty in considering the passage to the epithelial state as the result of a cellular division, which took place at a given moment of the phylogenetic evolution. The vanishing, or better the non-developing, of the internal ductules must then be considered as a second stage of the evolution.

An interesting confirmation of this opinion lies in the fact that two stages of a similar evolution are found as actual dispositions in other organs, which are, I believe, undoubtedly homogenetic, *i.e.*, the silk glands of insects. I have been engaged in the study of these organs for some time, and found them built on the same plan in four orders, viz., neuroptera, lepidoptera, diptera, and hymenoptera. They consist of two tubes uniting in the head, to form a single canal opening on the inferior lip of the larva. Each of these glandular tubes ordinarily consists of a small number of cells; it is quite common to find only two cells in a transverse section (fig. 3′).

But if we examine a similar section of the gland in a peculiar family of hymenoptera, the tenthredinida, we observe a very remarkable difference; the organ still consists of a tube, the wall of which is composed of flat cells, but, in addition to that, two series of spheroidal cells are attached to the sides. Each

of these cells contains a system of tiny canals running through their cytoplasm (fig. 2′, *i.d.*). These cells are the secreting elements; they continually cast the silk substance into the tube.

If we suppose that the silk gland was originally composed of a single row of cells, like the nephridium of the leeches, these two different structures of the silk glands may be regarded as corresponding to the two stages of the evolution which I have hypothetically indicated for the nephridium.

(*a.*) In the case of tenthredinida, the primary cells, after having divided several times in the course of evolution, have been disjoined from one another in such a

NEPHRIDIA

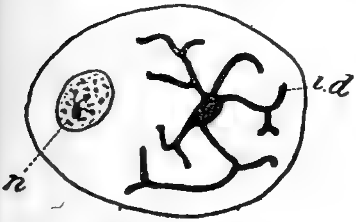

FIG. 1.—Leech.

(Intermediate stage, unknown)

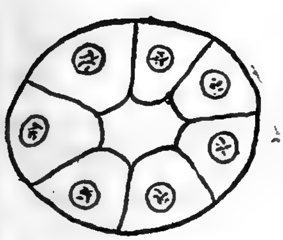

FIG. 3.—Vertebrate.

SILK GLANDS

(Merely intracellular stage, unknown)

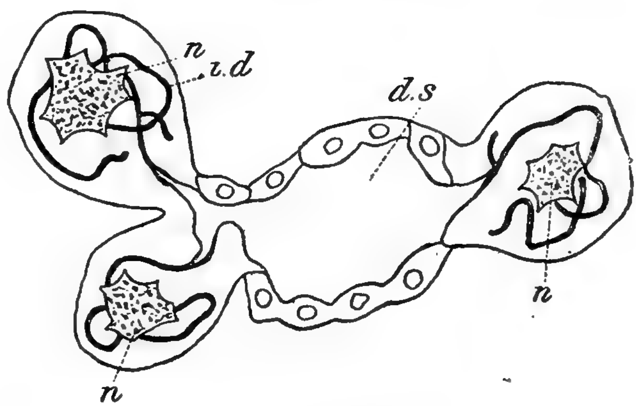

FIG. 2′.—Tenthredinid.

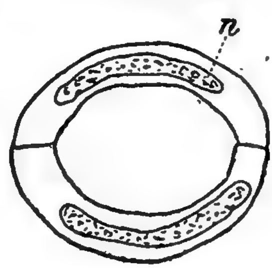

FIG. 3′.—Lepidopter.

way that some of them compose the wall of an epithelial excretory canal, and some others remain as appendages to that wall. The first have lost their internal ductules, the second keep them still, and are the silk-producing elements.

(*b.*) In the case of a simple tubular gland, as that of lepidoptera, the cells have not only divided and separated from one another, but have all lost their internal ductules, and secrete through their inner face only.

Now, although I give all this as mere supposition, it is desirable to know whether there exists or not among the nephridia any disposition corresponding to

the *tenthredinian* type of silk glands, which is composed of a central epithelial duct, together with several elements containing still *intracellular ductules.*

It seems to me that the existence of these two types of structure in organs so undoubtedly homogenetic as the silk glands of insects shows that there is no argument against the homology of the nephridia of the leeches with those of other forms, either lower or higher, in the fact that the cavities of one set are intracellular, those of the other intercellular.

At all events, the chief object of this communication is to show: (1) that cytological and histological differences, radical as they may be, must not always be considered as a final objection to the homogenetic relations between homologous organs; (2) that these differences deserve, however, to be taken into consideration, and that some interesting researches might be undertaken in that direction.

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6. *On Karyokinesis in the Fungi.* *By* Harold Wager, *F.L.S.*

Numerous observations have been made on nuclear division in the fungi which tend to show that in this group, as in the higher plants, it is indirect. In most cases, however, the observations seem to indicate that the division is very much simpler than in the higher plants.

Sadebeck and Fisch in Exoascus, and Hartog in Saprolegnia, have described a simple nuclear division in which the chromatic portion of the nucleus divides into two more or less equal parts. The author has described, in Peronospora, the division of the nucleus as taking place by the production, in the first place, of a number of chromosomes, which divide into two groups, each of which becomes a daughter nucleus. The division of the nucleus in these cases is certainly simpler, so far as the observations at present are concerned, than those in the higher plants.

At the Cardiff Meeting of the Association, however, the author described the structure of the nucleus, and the process of nuclear division in *Agaricus stercorarius*, and pointed out that not only had the nucleus a structure closely resembling that of the higher plants, but also that the nuclear division more nearly resembles that of the latter, inasmuch as a distinct equatorial plate and apparent spindle figure were formed.

More recently Rosen has described nuclear division among the Hymenomycetes in species other than those examined by the author. It will be useful to summarise briefly his results. According to him the nucleus possesses a distinct membrane, nucleolus, and homogeneous nuclear thread or threads. In the process of division the thread or threads divide up into a number of short pieces; then a separation of these into two groups takes place, both nucleolus and nuclear membrane persisting. The nucleus then divides into two halves; the nucleolus disappears, and two new nucleoli appear, one in each nucleus. Rosen concludes therefore that the division is a very simple one, and generalises thus for all the fungi. His results do not agree with the author's described prior to the appearance of his paper, except in the fact that the nucleolus persists for a long time.

Lister's beautiful observations on division of the nucleus in the Myxomycetes do not support Rosen's generalisation, for according to the former a distinct spindle figure is formed, and the process of division closely resembles that which takes place in the higher plants, except, perhaps, in the longitudinal splitting of the threads, which has not yet been seen.

Gjurasin has very recently published a paper on nuclear division in the Asci of *Peziza vesiculosa,* in which he shows that not only is a spindle figure produced, but that even the protoplasmic radiations at the poles of the spindle are visible. He notes here, also, the extraordinary persistence of the nucleolus.

The observations recently made by the author on certain species of the Agaricineæ, *Agaricus* (*Stropharia*) *stercorarius* and *Amanita muscarius* all tend to show that we are dealing with precisely the same changes in the indirect division of the nucleus as in those of the higher plants. The nucleus consists of a membrane, nuclear network, and nucleolus; the network is composed either of a single thread or more than one: it consists of a ground substance, which stains light blue, in which more deeply stained granules are embedded. The nucleus takes up a con-

siderable portion of the diameter of the basidium. When division is about to take place the nuclear threads break up into a number of short pieces; the nuclear granules run together and give these pieces a homogeneous appearance. The membrane gradually becomes more and more indistinct, especially at the upper end of the nucleus; the nuclear threads group themselves at this point and form an equatorial plate, they become shorter and thicker and now stain bright red instead of blue; the nucleolus persists all this time, but has been gradually getting fainter; the chromosomes at the same time becoming bright red. A nuclear spindle now appears; it consists of a few threads, the exact number of which could not be made out; and in *Stropharia stercorarius,* but not so clearly in *Amanita muscarius,* a deeply stained dot (centrosome?) can be made out at each pole of the spindle. The chromosomes now divide into two groups, which begin to move along the spindle to the poles. The nucleolus has by this time almost entirely disappeared. When the chromosomes reach the poles of the spindle they become condensed into two irregular masses which stain red. A nuclear membrane then appears around each, and from these red masses threads apparently radiate more or less regularly. The nuclei then increase in size, a new nucleolus appears in each, and a distinct network is formed, so that the nuclei now resemble the original nucleus of the basidium. Then these two nuclei begin to divide, the process being exactly similar to the original division, and four nuclei are produced, one for each spore of the basidium.

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7. *On Variation of Fecundity in* Trifolium pratense *and its varieties and* Trifolium medium. *By* WILLIAM WILSON.

Trifolium pratense.—Purple Clover is known as being prolific in seeds. While there exist several varieties of it, caused perhaps by the peculiar conditions under which each exists, such as the soil, none of these varieties is so good a seed-producer as the normal type, as far as is known.

The most important variety, supposed by some to be a hybrid between Purple Clover and Zigzag Clover, and known as *Trifolium perenne,* Perennial Red, and as the Cowgrass of commerce, has the commercial value of its seeds higher than those of Purple Clover on account of the weakness in seed-producing. Although the plants may yield as many flowers, the seed is deficient, while it has a more penetrating root.

Touching next upon *Trifolium medium,* Zigzag Clover or Cowgrass of botany, I find from observations on plants in an endigenous state, and by transplanting, that the seeds are very few in number.

There is a form of *Trifolium,* which differs in characters from all the forms mentioned, which I call Perennial Meadow Clover, which is an abundant seed-producer in its endigenous condition.

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8. *On the Cortex of* Tmesipteris tannensis, *Bernh. By* R. J. HARVEY GIBSON, *M.A., F.L.S.*

After reference to the existing literature on the subject, the author drew attention to the difference of opinion on the nature and mode of deposit of the brown substance contained in the cells of the inner cortex of *Tmesipteris tannensis* (Bernh.) and other species. He supports the view held by Bertrand and Dangeard that the substance is deposited in the cell wall, not in the cell cavity, and showed that by means of suitable reagents and care in manipulation, the presence of both tannin and iron could be demonstrated in the deposit. He suggested the possibility of the tannate of iron having been absorbed from the roots of the tree ferns on which *Tmesipteris* is probably not an epiphyte but a parasite. Evidence was also adduced that there exists in the stem and rhizome of *Tmesipteris* a true endodermis with cuticularised radial walls, lying between the layer containing the brown deposit and the pericycle.

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9. *On Lime Salts in relation to some Physiological Processes in the Plant.* *By* Dr. J. Clark.

The seeds of many Alpine and other plants when germinating at a low temperature are incapable of utilising their reserve food-supplies to any great extent, unless there be 1 to 15 per cent. of carbonate of lime present in the soil, the quantity varying with different species. When germination takes place at a low temperature, say 5° C., on a soil where the carbonate of lime falls below the necessary minimum, the seedlings perish. When seeds of the same species germinate at a temperature varying from 15° C. to 30° C. in a soil poor in lime, nearly the whole of the reserve food-supply is utilised, and if subsequently removed to a more congenial temperature, the seedlings continue to grow in a normal manner. Either lime or a high temperature is therefore necessary for the translocation of material from the seed to the growing parts of the seedling. The varying amount of carbonate of lime present in the soil must consequently be a powerful factor in determining the local distribution of plants.

In connection with the occurrence and distribution of lime salts in the living plant, the author has been led to the conclusion that the disappearance in the spring of the calcium oxalate accumulated in the bark of many trees during the previous autumn is probably due to the activity of certain bacteria. These bacteria are capable under favourable conditions of converting calcium oxalate into calcium carbonate, and are found in the early spring associated with the cells in which the oxalate is stored.

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10. *On the development of the 'Ovipositor' in the Cockroach* (Periplaneta orientalis). *By* Professor A. Denny.

It is well known that in the adult female of this familiar insect the abdomen is possessed of only seven sterna, while in the male we find nine well developed. That the two missing sterna in the female are represented by the 'ovipositor' has long been known, but up to the present time their development does not appear to have been completely worked out. An examination of a complete series of preparations has brought to light several new facts which necessitate a revision of the usually accepted views concerning the morphology of this organ. In the first stage (recently hatched) the abdomen presents nine sterna similarly developed in both sexes, and in each case the terminal sternum is characterised by a pair of unjointed 'styles' (a feature peculiar to the male in the adult). The ninth sternum at this stage shows a posterior median cleft, which in subsequent stages deepens and widens until the body of the sternum is almost divided into separate halves. In an early stage of development two pairs of simple unjointed appendages (the gonapophyses) appear in connection with the eighth and ninth sterna. The appendages of the ninth sternum at first lie upon its dorsal surface and are not visible from the exterior, but are afterwards brought into view by the division of the sternum. The separated halves of the ninth sternum by degrees assume an appendage-like outline, and eventually become the so-called outer pair of 'posterior gonapophyses.' Thus, in the ovipositor of the adult the three pairs of appendages are not homologous (as generally supposed), there being a pair of anterior gonapophyses and a pair of posterior (inner) gonapophyses which originate as appendages of the eighth and ninth sterna respectively, while the so-called 'outer' posterior gonapophyses have a different origin, being formed by metamorphosis of the ninth sternum. The eighth sternum gradually diminishes in size up to the final stage, where it is represented by little more than the small median plate which supports the spermatheca (which has hitherto been regarded as representing the ninth sternum), and a pair of plates upon which rest the anterior gonapophyses, generally described as basal joints of these appendages. Further, the thin plate which carries the aperture of the uterus is not the eighth sternum (as usually supposed), but originates as a fold of the intersternal membrane between segments seven and eight.

Section E.—GEOGRAPHY.

President of the Section—Henry Seebohm, Sec.R.G.S., F.L.S., F.Z.S.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

[PLATE V.]

Geography, the child of Mathematics and Astronomy, stands in the relation of mother to half a dozen other sciences, which have long ago left the parental roof to establish sections of their own. Like every other science, geography is so closely connected with, and dependent on, its allied sciences that it is impossible to treat of the one without invading the province of the others. No one supposes that the making of maps is the whole duty of the geographer. The accurate delineation of the trend of coast-lines, the courses of rivers, the heights of mountains, the depths of seas, or the position of towns is only the skeleton which underlies the real science of geography.

The study of geography may be divided into various sections, but it must always be remembered that they dovetail into each other, as well as into the allied sciences, to such an extent that no hard-and-fast line can be drawn between them. The object of dividing so comprehensive a section as that of geography into sub-sections is more practical than scientific. The classification of facts is an important aid to memory, and introduces order into what might otherwise seem to be a chaos of knowledge.

The foundation of all geography is exploration; but before the traveller can do good geographical work he must acquire the necessary knowledge embraced in the science of cartography. This includes a practical acquaintance with the various instruments used in making a survey, the necessary mathematical and astronomical knowledge required for their use, and a familiarity with the accepted mode of expressing the geographical facts that may be acquired on a chart or map. Exploration may then be undertaken with some chance of ultimate success, but the object of exploration must be something more than the filling up of blanks in our maps. Many other subjects must receive attention, subjects which are collectively included in the term physical geography, but which require treatment under different heads. Of these the most obvious is the geographical distribution of light and heat, as well as the more fitful alternations of wind and rain with calm and drought; in other words, the numerous causes which combine to produce climate. Meteorology or climatology, the geography of the air, is a most important branch of geography in general; and when we come to inquire into the changes which have taken place in the climate of different parts of the earth's surface, especially those which have affected the Polar Basin, we enter upon a subject which has claimed a large share of the attention of geologists, who have also made a profound study of the geographical distribution of the various kinds of rock which are found on the crust of the earth. Another sub-section of great importance is the geographical distribution of organic life. The geographical ranges of the species and genera, both of plants and animals, have become a subject of vastly increased importance since so much attention has been directed to the

theory of evolution, and the paramount importance of the human race is so great that ethnological geography may fairly claim to be treated as a sub-section apart from the study of the rest of the fauna of a country. Inasmuch as a map with the towns left out is only half a map, the geographer cannot afford to neglect the races of men with which he comes in contact, nor the remains (architectural or otherwise) which existing nations have produced or past races have left behind them.

I propose on the present occasion to elaborate these subjects at greater detail, and, with your permission, to take the Polar Basin as an example.

There is only one Polar Basin; the relative distribution of land and water and the geographical distribution of light and heat in the Arctic region is absolutely unique. In no other part of the world is a similar climate to be found. The distribution of land and water round the South Pole is almost the converse of that round the North Pole. In the one we have a mountain of snow and ice covering—it may be a continent, it may be an archipelago, but in any case a lofty mass of congealed water surrounded by an ocean stretching away with very little interruption from land to the confines of the tropics. In the other we have a basin of water surrounding a comparatively flat plain of pack ice, some of which is probably permanent (the so-called palæocrystic sea), but most of which is driven hither and thither in summer by winds and currents, and is walled in by continental and island barriers broken only by the narrow outlets of Behring Strait and Baffin's Bay and the broader gulf which leads to the Atlantic Ocean, and even that interrupted by Iceland, Spitzbergen, and Franz Josef Land. When we further remember that this gulf is constantly conveying the hot water of the tropics to the Arctic Ocean, and that every summer gigantic rivers are pouring volumes of comparatively warm water into this ocean, we cannot but admit that the climatic conditions near the two poles differ widely from each other.

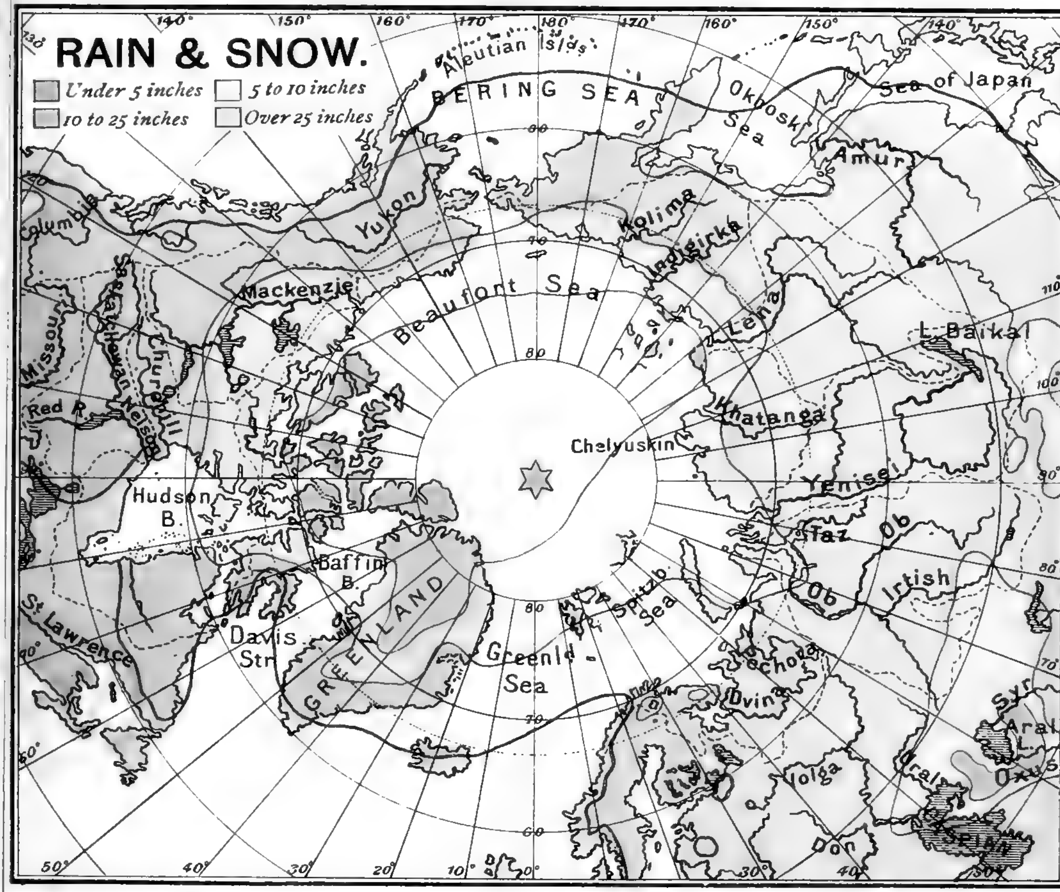
In looking at a map of the Polar Basin one cannot help remarking the curious fact that the North Pole is so very nearly central, and a glance at the southern hemisphere also shows a rough sort of symmetry in the distribution of land and water round the South Pole. It is a curious coincidence if this be only accident.

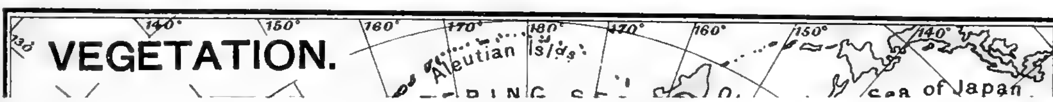
The history of the

EXPLORATION

of the Polar Basin is a very long and a very tragic story. Much has been done, but much remains to do. The unexplored regions of the Polar Basin may be estimated at a million square miles. No part of the world presents greater difficulties to the explorer. Many brave men have perished in the enterprise, and more have only just succeeded in passing through the ordeal of hunger and cold with their lives. For the most part the heroic endurance of the tortures of famine has shown a marvel of discipline, though occasionally the commanders of the expeditions have had to enforce obedience to the verge of cruelty, both in the case of men and of dogs. There are, indeed, a few ghastly stories of mutinous men who have been shot, and of cases where it has been found necessary to resort to human food to save the lives of the survivors, but the records of Arctic exploration are records of which any nation might be proud.

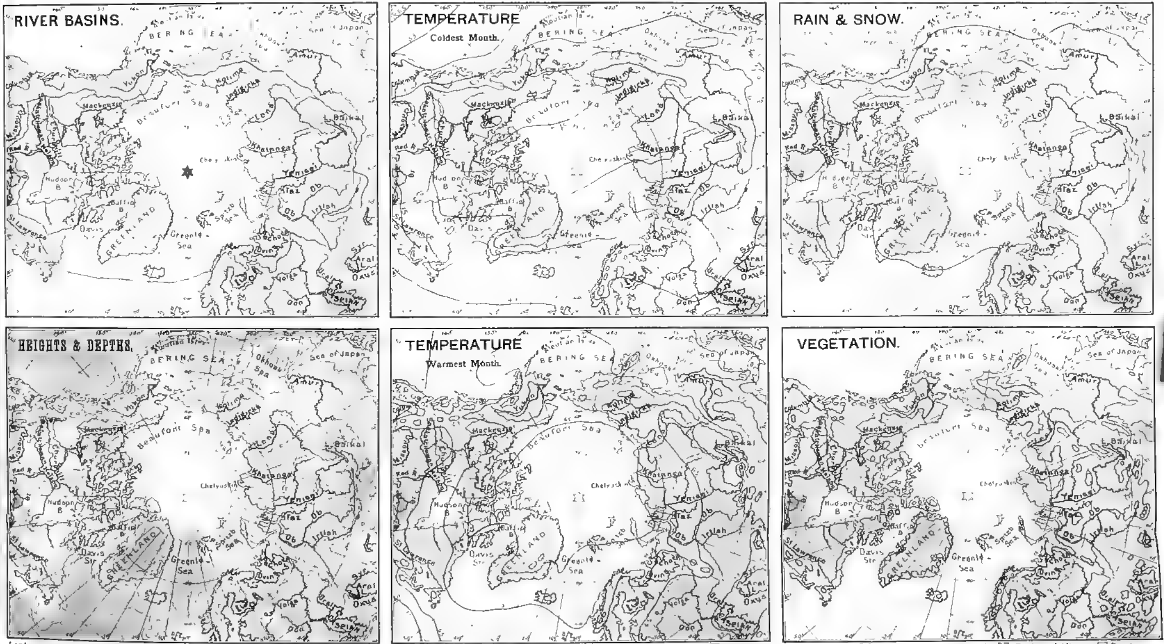
Of recent years there has been but little done to explore the unknown parts of the Polar Basin. Adventurous journeys in Central Africa and Central Asia have somewhat eclipsed the exploration of the Arctic regions. Two visits to Greenland cannot, however, be entirely passed by in silence. In the summer of last year an expedition went to the north of Greenland under the command of Lieutenant Peary, succeeded in reaching latitude 82°, and added material evidence to prove that Greenland is an island. The expedition sailed on June 6, 1891, steamed up Baffin's Bay and Smith's Sound, and on July 25 dismissed the ship and established themselves in winter quarters in McCormick Bay, on the north side of Murchison Sound, in latitude 78°. They laid in a stock of game for the winter, guillemots and reindeer. A most interesting proof of the successful organisation of the expedition is the fact that Mrs. Peary was one of the party, and was able to accompany her husband on his sledge trip which started on the 18th of the following April.





Greenland. The Norwegian at Hammerfest, about latitude 70°, is dependent for his firewood upon the Gulf Stream, which brings him an ample supply from the Gulf of Mexico, whilst the Eskimo on the Greenland coast, in the same latitude, trusts

SIX POLAR CHARTS illustrating Mr HENRY SEEBOHM'S PRESIDENTIAL ADDRESS, Nottingham September, 1893



Land — Below Sea Level. 0–500 ft. 500–2000 ft. 2000–6000 ft. 6000–12,000 ft. Over 12,000 ft.
Sea.— Depth under 100 fath. 100–500 fath. 500–1000 fath. 1000–2000 fath. Over 2000 fath.

Actual Mean Temperature of Month: Under −35° — −35° to −10° — −10° to +15° — 15° to 40° — 40° to 55° — 55° to 66° — 66° to 77° — Over 77°

Woodland. Grassland (Steppe, Prairie, &c.). Tundra and Alpine. Desert. Snow and Ice.

It took them a week in their dog sledges to round Inglefield Gulf, during which they discovered thirty glaciers, ten of them of the first magnitude. During the next three months they explored the north coast of Greenland, as far east as longitude 34° W., when a great bay was reached which they named Independence Bay, as they discovered it on July 4. The northern shore of this bay was free from snow and ice. On August 6 they regained their winter quarters in McCormick Bay. On the 8th the steamer arrived, and on the 24th they started for home, reaching Philadelphia on September 23. During the sledge journey they travelled for a fortnight at an average elevation of 8,000 feet above the sea. Besides their important additions to the map of Greenland, the suggestive fact that the thermometer can rise to 41° F., and torrents of rain can fall in the middle of February as far north as latitude 78°, must be regarded as a valuable discovery.

It was hardly to be expected that so successful a journey should not be followed by a second attempt in order to follow up the discoveries of the first. Peary has already started for the north of Greenland with a more carefully organised staff for a longer expedition. They expect to be absent two years or more. It has been arranged to spend the coming winter not far from their previous quarters. In March they hope to start for Independence Bay, which was discovered on the previous expedition, and there the party will divide, with the object of completing the survey of the coast line of Greenland by reaching Cape Bismarck if possible, and at the same time to explore the northern coast line of Independence Bay, hoping that it may land them further north than the highest point yet reached by any Arctic traveller.

In the summer of 1888 Dr. Nansen was bold enough to cross the continent of Greenland about latitude 64°, reaching an altitude of 9,000 feet, and he told his story to this Section in his own simple words on his return. The distance across was about ten degrees, and the highest point was about one-third of the way across from the east coast. If the scientific results were necessarily somewhat meagre, Dr. Nansen established a reputation for bravery and physical endurance which he hopes to increase by an attempt to reach the North Pole. The 'Fram' has already started from Hammerfest, and was telegraphed a few weeks ago from the east coast of Norway. The intention is to enter the Kara Sea and to push northwards and eastwards, hoping that the warm currents caused by the great Siberian rivers will enable them to get well into the ice before winter begins. Once frozen into the pack ice, Nansen hopes to be carried by the currents somewhere near the North Pole, and, after drifting for two or three years, he hopes finally to emerge from his ice prison somewhere on the east coast of Greenland. Foolhardy as the expedition appears, it is nevertheless planned with great skill, and its chances of success are supposed to be based upon a sufficiently accurate knowledge of the ocean currents of the Polar Basin.

These currents, so far as they are known, are very interesting. The Mackenzie and the great Siberian rivers flow into the Polar Basin, and the current through Behring Strait is supposed to do the same; but both these sources of supply can only be regarded as of minor importance. Between Spitzbergen and Finmark, however, the Gulf Stream enters the Polar Basin 300 or 400 miles wide. To compensate for these inward currents there are two outward currents, one on each side of Greenland, which, coming from the centre of cold, do their best to intensify the rigours of that mountainous island.

Nansen hopes that the current which carried the 'Jeannette' from Herald Island, north of Behring Strait, in a north-westerly direction, for 500 or 600 miles is the same current that flows down the east coast of Greenland, and he bases his hopes upon three facts. First, that many articles from the wreck of the 'Jeannette' were found on an ice floe off the south coast of Greenland three years afterwards; second, that a harpoon-thrower of a pattern unknown except in Alaska was picked up on the south-west coast of Greenland; and, third, that drift-wood supposed to be of Siberian origin is stranded regularly in considerable quantity on the coasts of Greenland. The Norwegian at Hammerfest, about latitude 70°, is dependent for his firewood upon the Gulf Stream, which brings him an ample supply from the Gulf of Mexico, whilst the Eskimo on the Greenland coast, in the same latitude, trusts

to a current from the opposite direction to bring him his necessary store of wood from the Siberian forests.

We can only hope that Nansen will find the currents as favourable to his needs, and that so much bravery may be supported by good luck.

By no means the least important physical feature of the Polar Basin is its gigantic

RIVER SYSTEMS.

The rivers which flow into the Arctic Ocean are some of them amongst the greatest in the world.

Some idea of the relative sizes of the drainage areas of a few of the best known rivers may be learnt from the following table, in which the Thames, with a drainage area of 6,000 square miles, is the unit:—

9	Thames	equal	1 Elbe (54,000).
2	Elbes	„	1 Pechora (108,000).
2½	Pechoras	„	1 Danube (270,000).
2	Danubes	„	1 Mackenzie (540,000).
2	Mackenzies	„	1 Yenisei (1,080,000).
2	Yeniseis	„	1 Amazon (2,160,000).

Perhaps a more scientific classification of rivers would be to call those with a drainage area (between 2,560,000 and) over 1,280,000 square miles rivers of the first magnitude, a category which contains the Amazon alone. There are ten rivers of the second magnitude, with drainage areas between 1,280,000 and 640,000 square miles (Ob, Congo, Mississippi, La Plata, Yenisei, Nile, Lena, Niger, Amur, Yangtse). There are twelve rivers of the third magnitude, with drainage areas between 640,000 and 320,000 square miles (Mackenzie, Volga, Murray, Zambesi, Saskatchewan, Ganges, St. Lawrence, Orange, Orinoco, Hoang Ho, Indus, and Bramaputra). There are more than a dozen rivers of the fourth magnitude, with drainage areas between 320,000 and 160,000 square miles, but none of them empties itself into the Arctic Ocean. They include the Danube, Euphrates, and several of the African and South American rivers. Of the numerous rivers which are of the fifth magnitude, with drainage areas between 160,000 and 80,000 square miles, the Pechora belongs to the Polar Basin. The number of rivers of lesser magnitude is legion, and it is only necessary to quote one of each as an example.

6th	magnitude	(80,000 to 40,000), Rhine.
7th	„	(40,000 to 20,000), Rhone.
8th	„	(20,000 to 10,000), Garonne.
9th	„	(10,000 to 5,000), Thames.

There is nothing that makes a greater impression upon the Arctic traveller than the enormous width of the rivers. The Pechora is only a river of the fifth magnitude, but it is more than a mile wide for several hundred miles of its course. The Yenisei is more than three miles wide for at least a thousand miles, and a mile wide for nearly another thousand. Whymper describes the Yukon as varying from one to four miles in width for three or four hundred miles of its length. The Mackenzie is described as averaging a mile in width for more than a thousand miles, with occasional expansions for long distances to twice that size.

The drainage area does not measure the size of the Arctic rivers at all adequately. Though the rainfall of many of them is comparatively small, the size of the rivers is relatively very large, owing to the sudden melting of the winter's accumulation of snow, which causes an annual flood of great magnitude, like the rising of the Nile. Even on the Amur in Eastern Siberia, and on the Yukon in Alaska, the annual flood is important enough, but on the rivers which flow north into the Polar Sea the damming up of the mouths by the accumulations of ice produces an annual deluge, frequently extending over thousands of square miles, a catastrophe the effects of which have been much underrated and never adequately described.

If we assume that the unknown regions are principally sea, then the Polar

Basin, including the area drained by all rivers flowing into the Arctic Sea, may be roughly estimated to contain about 14,000,000 square miles, of which half is land and half water. In the coldest part of the basin the land is either glacier or tundra, and in the warmer parts it is either forest or steppe.

Greenland, the home of the

GLACIER

and the mother of the icebergs of the Northern Atlantic, rises 9,000 or 10,000 feet above sea level, whilst the sea between that lofty plateau and Scandinavia is the deepest known in the Polar Basin, though it is separated from the rest of the Atlantic by a broad belt or submarine plateau connecting Greenland across Iceland and the Faroes with the British Islands and Europe. Iceland, Spitzbergen, and Novaya-Zemlia, the latter a continuation of the Urals, are all mountainous and full of glaciers. The glaciers of Southern Alaska are some of the largest in the world. The glaciers and the icebergs have a literature of their own, and we must pass them by to say a word or two about

THE TUNDRA.

The Arctic Sea, which lies at the bottom of the Polar Basin, is fringed with a belt of bare country, sometimes steep and rocky, abruptly descending in more or less abrupt cliffs and piles of precipices to the sea, but more often sloping gently down in mud banks and sand hills representing the accumulated spoils of countless ages of annual floods, which tear up the banks of the rivers and deposit shoals of detritus at their mouths, compelling them to make deltas in their efforts to force a passage to the sea. In Norway this belt of bare country is called the Fjeld, in Russia it is known as the Tundra, and in America its technical name is the Barren Grounds. In the language of science it is the country beyond the limit of forest growth.

In exposed situations, especially in the higher latitudes, the tundra does really merit its American name of barren ground, being little else than gravel beds interspersed with bare patches of peat or clay, and with scarcely a rush or a sedge to break the monotony. In Siberia at least this is very exceptional. By far the greater part of the tundra, both east and west of the Ural Mountains, is a gently undulating plain, full of lakes, rivers, swamps, and bogs. The lakes are diversified with patches of green water plants, amongst which ducks and swans float and dive; the little rivers flow between banks of rush and sedge; the swamps are masses of tall rushes and sedges of various species, where phalaropes and ruffs breed, and the bogs are brilliant with the white fluffy seeds of the cotton grass. The groundwork of all this variegated scenery is more beautiful and varied still—lichens and moss of almost every conceivable colour, from the cream-coloured reindeer moss to the scarlet-cupped trumpet moss, interspersed with a brilliant alpine flora, gentians, anemones, saxifrages, and hundreds of plants, each a picture in itself, the tall aconites, both the blue and yellow species, the beautiful cloudberry, with its gay white blossom and amber fruit, the fragrant *Ledum palustre* and the delicate pink *Andromeda polifolia.* In the sheltered valleys and deep watercourses a few stunted birches, and sometimes large patches of willow scrub, survive the long severe winter, and serve as cover for willow grouse or ptarmigan. The Lapland bunting and red-throated pipit are everywhere to be seen, and certain favoured places are the breeding grounds of snipe, plover, and sandpipers of many species. So far from meriting the name of barren ground, the tundra is for the most part a veritable paradise in summer. But it has one almost fatal drawback—it swarms with millions of mosquitoes.

The tundra melts away insensibly into the

FOREST,

but isolated trees are rare, and in Siberia there is an absence of young wood on the confines of the tundra. The limit of forest growth appears to be retiring southward, if we may judge from the number of dead and dying stumps but this may

be a temporary or local variation caused by exceptionally severe winters. The limit of forest growth does not coincide with the isotherms of mean annual temperature, nor with the mean temperature for January nearly so closely as it does with the mean temperature for July. It may be said to approximate very nearly to the July isotherm of 53° F. We may therefore assume that a six-foot blanket of snow prevents the winter frosts from killing the trees so long as they can be revivified by a couple of months of summer heat above 50° F.

The limit of forest growth is thus directly determined by geographical causes. In Alaska and in the Mackenzie Basin it extends about 300 miles above the Arctic Circle, but in Eastern Canada the depression of Hudson's Bay acts as a vast ice-house and the forest line falls 500 miles below the Arctic Circle, whilst on the east coast of Labrador the Arctic current from Baffin's Bay sends it down nearly as far again. On the other side of the Atlantic the limit of forest growth begins on the Norwegian coast on the Arctic Circle, gradually rises until it reaches 200 miles farther north in Lapland, is depressed again by the ice-house of the White Sea, but has recovered its position in the valley of the Pechora, which is rather more than maintained until a second vast ice-house, the Sea of Okotsk, combined with Arctic currents, repeats the depression of Labrador in Chuski Land and Kamchatka.

There are no trees on Novaya-Zemlia. Two or three species of willow grow there, but they are dwarfs, seldom attaining a height of three inches. Novaya-Zemlia enjoys a comparatively mild winter, the mean temperature of January, thanks to the influence of the Gulf Stream, being 15° F. above zero in the south, and only 5° F. below zero in the north. The absence of trees is due to the cold summers, the mean temperature of July not reaching higher than 45° F. in the south, whilst in the north it only reaches 38° F.

The Indians of Canada have discovered that when they want to find water in winter it is easiest reached under thick snow, the thinnest ice on the river or lake being found under the thickest blanket of snow. On the same principle the tree roots defy the severe winters protected by their snow shields, but they must have a certain temperature (above 50° F.) to hold their own in summer.

The influence of the snow blanket is very marked in determining the depths to which the frost penetrates beneath it. Thus we find that a Norwegian writer, alluding to latitude 62°, remarks 'that the ground is frozen from one to two and a half feet in winter, but this depends upon how soon the snow falls. Higher up the mountains the ground is scarcely frozen at all, owing to the snow falling sooner, and, in fact, if the snow falls very early lower down it is scarcely frozen to any depth.' Similar facts have been recorded from Canada in latitude 53°. 'On this prairie land, when there is a good fall of snow when the winter sets in, the frost does not penetrate so deep as when there is no snow till late.' Another writer a little further south, in latitude 51°, says: 'I am safe in saying that the frost penetrates here to an average of five feet, except when we have had a great depth of snow in the beginning of winter, in which case it does not penetrate nearly so far.'

It is not so easy to explain the boundary line between the forest and the

STEPPE.

There are two great steppe regions in the Polar Basin, one in Asia and the other in America. The great Barabinski steppe in South-west Siberia stretches with but slight interruptions across Southern Russia into Bulgaria. The great prairie region of Minnesota and Manitoba reaches the Mackenzie Basin, and outlying plains are found almost up to the Great Slave Lake. The cause of the treeless condition of the steppes or prairies has given rise to much controversy. My own experience in Siberia convinced me that the forests were rocky, and the steppes covered with a deep layer of loose earth, and I came to the conclusion that on the rocky ground the roots of the trees were able to establish themselves firmly so as to defy the strongest gales, which tore them up when they were planted in light soil. Other travellers have formed other opinions. Some suppose that the prairies were once covered with trees which have been gradually destroyed by fires. Others

suggest that the earth on the treeless plains contains too much salt or too little organic matter to be favourable to the growth of trees. No one, so far as I know, has suggested a climatic explanation of the circumstance. Want of drainage may produce a swamp and the deficiency of rainfall may cause a desert, both conditions being fatal to forest growth, but no one can mistake either of these treeless districts for a steppe or prairie. The

ANTHROPOLOGY

of the Polar Basin presents many points of interest. On the American coasts of the Arctic Ocean the Eskimo lives a very similar life to the Lapp in Norway and the Samoyede in the tundras of Siberia. These races of men resemble each other very much in their personal appearance, and still more so in their habits. Their straight black hair, with little or no beard, their dark and obliquely set eyes, their high cheek bones and flat noses, and their small hands and feet testify to their Mongoloid origin. They are all indebted to the reindeer for their winter dress and for much of their food, and they all have dogs; but the Eskimo travel only with dogs, and the Lapp only with reindeer, whilst the Samoyede uses both dog sledges and reindeer sledges. They all lead a nomadic life, trapping fur-bearing animals in winter and fishing in summer; they resemble each other in many other customs and beliefs, but they are nevertheless supposed to have emigrated to the Arctic regions from independent sources, and many characters in which they resemble each other are supposed to have been independently acquired.

The various races which inhabit the Polar Basin below the limit of forest growth are too numerous to be considered in detail.

Most zoologists divide the Polar Basin into two zoological regions, or, to be strictly accurate, they include the Old World half of the Polar Basin in what they call the Palæarctic region, and the New World half in the Nearctic region; but recent investigations have shown that these divisions are unnatural and cannot be maintained. Some writers unite the two regions together under the name of the Holarctic region, whilst others recognise a circumpolar Arctic region above the limit of forest growth, and unite in a second region the temperate portions of the northern hemisphere. In the opinion of the last-mentioned writers the circumpolar Arctic region differs more from the temperate regions of the northern hemisphere than the American portion of the latter does from the Eurasian portion.

The fact is that

LIFE AREAS,

or zoo-geographical regions, are more or less fanciful generalisations. The geographical distribution of animals, and probably also that of plants, is almost entirely dependent upon two factors, *climate* and *isolation*, the one playing quite as important a part as the other. The climate varies in respect of rainfall and temperature, and species are isolated from each other by seas and mountain ranges. The geographical facts which govern the zoological provinces consequently range themselves under these four heads. It is at once obvious that the influences which determine the geographical distribution of fishes must be quite different from those which determine the distribution of mammals, since the geographical features which isolate the species in the one case are totally different from those which form impassable barriers in the other. It is equally obvious that the climatic conditions which influence the geographical range of mammals must include the winter cold as well as the summer heat, whilst those which determine the geographical distribution of birds, most of which are migratory in the Arctic regions, is entirely independent of any amount of cold which may descend upon their breeding grounds during the months which they spend in their tropic or sub-tropic winter quarters.

Hence all attempts to divide the Polar Basin into zoological regions or provinces are futile. Nearly every group of animals has zoological regions of its own, determined by geographical features peculiar to itself, and any generalisations from these different regions can be little more than a curiosity of science. The mean temperature or distribution of heat can be easily ascertained. It is easy to generalise so as to arrive at an average between the summer heat and the winter cold, because they can be both expressed in the same terms. When, however, we

seek to generalise upon the distribution of animal or vegetable life, how is it possible to arrive at a mean geographical distribution of animals? How many genera of mollusks are equal to a genus of mammals, or how many butterflies are equal to a bird?

If there be any region of the world with any claim to be a life area, it is that part of the Polar Basin which lies between the July isotherm of 50° or 53° F. and the northern limit of organic life. The former corresponds very nearly with the northern limit of forest growth, and they comprise between them the barren grounds of America and the tundras of Arctic Europe and Siberia.

The fauna and flora of this circumpolar belt are practically homogeneous; many species of both plants and animals range throughout its whole extent. It constitutes a circumpolar Arctic region, and cannot consistently be separated at Behring Strait into two parts of sufficient importance to rank even as sub-regions.

Animals recognise facts, and are governed by them in the extension of their ranges; they care little or nothing about generalisations. The mean temperature of a province is a matter of indifference to some plants and to most animals. The facts which govern their distribution are various, and vary according to the needs of the plant or animal concerned. To a migratory bird the mean annual temperature is a matter of supreme indifference. To a resident bird the question is equally beside the mark. The facts which govern the geographical distribution of birds are the extremes of temperature, not the means. Arctic birds are nearly all migratory. Their distribution during the breeding season depends primarily on the temperature of July, which must range between 53° and 35° F. It is very important, however, to remember that it is actual temperature that governs them, not isotherms corrected to sea level. If an Arctic bird can find a correct isotherm below the Arctic Circle by ascending to an elevation of 5,000 or 6,000 feet above the level of the sea, it avails itself of the opportunity. Then the region of the Dovrefeld above the limit of forest growth is the breeding plan of many absolutely Arctic birds; but this is not nearly so much the case on the Alps, because the cold nights vary too much from the hot days to come within the range of the birds' breeding grounds. Here, again, the mean daily temperature is of no importance. It is the extreme of cold which is the most potent factor in this case, and no extreme of heat can counterbalance its effect.

In estimating the influence of elevation upon temperature it has been ascertained that it is necessary to deduct about 3° F. for every thousand feet. The

ISOTHERMAL LINES

are very eccentric in the Polar Basin. The mean temperature of summer is quite independent of that of winter. The isothermal lines of July are regulated by geographical causes which do not affect those of December, or operate in a contrary direction. The Gulf Stream raises the mean temperature of Iceland during winter to the highest point which it reaches in the Polar Basin, viz., 30° to 35° F., whilst in summer it prevents it from rising above 45° and 50° F., a range of only 15°. In the valley of the Lena in the same latitude the mean temperature of January is 55° to 50° F. below zero, whilst that of July is 60° to 65° F. above zero, a range of 115°.

The close proximity of the Pacific Ocean has a much less effect on the mean temperature at Behring Strait, which is in the same latitude as the north of Iceland. The mean temperature for January is zero, whilst that for July is 40° F. The mean temperature for January in the same latitude in the valley of the Mackenzie is 25° below zero, whilst that for July is 55° F. In this case the contrast of the ranges is 40 and 80, which compared with 15 and 115 is small, but the geographical conditions are not the same. Behring Sea is so protected by the Aleutian chain of islands that very little of the warm current from Japan reaches the straits. It is deflected southwards, so the Aleutian Islands form a better basis for comparison. Their mean temperature for January is 35° F., whilst that for July is 50° F., precisely the same difference as that to be found in Iceland.

The influence of geographical causes upon climate being at present so great, it is easy to imagine that changes in the distribution of land and water may have had an equally important influence upon the climate of the Polar Basin during the

recent cold age, which geologists call the Pleistocene period. It is impossible for the traveller to overlook the evidences of this so-called Glacial period in the Polar Basin, and whether we seek an explanation of the geographical phenomena from the astronomer or the geologist, or both, it is impossible to ignore the geographical interest of the subject.

No sciences can be more intimately connected than geography and

GEOLOGY.

A knowledge of geography is absolutely essential to the geologist. To discriminate between one kind of rock and another is a comparatively small part of the work of the geologist. To ascertain the geographical distribution of the various rocks is a study of profound interest. If the geologist owes much to the geographer, the latter is also largely indebted to the labours of the former. The geology of a mountain range or an extended plain is as important to the physical geographer as the knowledge of anatomy is to the figure painter.

The geology of the Polar Basin is not very accurately known, and the subject is one too vast to be more than mentioned on an occasion like the present; but the evidences of a comparatively recent ice age in eastern America and western Europe are too important to be passed by without a word.

In the sub-Arctic regions of the world there is much evidence to show that the climate has in comparatively recent times been Arctic. The present glaciers of Central Europe were once much greater than they are now, and even in the British Islands glaciers existed during what has been called the ice age, and the evidence of their existence in the form of rocks, upon which they have left their scratches and heaps of stones, which they have deposited in their retreat, are so obvious that he who runs may read. Similar evidence of an ice age is found in North America, and to a limited extent in the Himalayas, but in the alluvial plains of Siberia and North Alaska, as might be expected, no trace of an ice age can be found.

Croll's hypothesis that an ice age is produced when the eccentricity of the earth's orbit is unusually great has been generally accepted as the most plausible explanation of the facts. It is assumed that during the months of perihelion evaporation is extreme, and that during the months of aphelion the snowfall is considerably increased. The effect of the last period of high eccentricity is supposed to have been much increased by geographical changes. The elevation of the shallow sea which connects Iceland with Greenland on the one hand, and the south of Norway and the British Islands on the other, would greatly increase the accumulation of snow and ice in those parts of the Polar Basin where evidence of a recent ice age is now to be found; whilst the depression of the lowlands on either side of the Ural Mountains, so as to admit the waters of the Mediterranean through the Black and Caspian Seas, might prevent any glaciation in those parts of the Polar Basin where no evidence of such a condition is now discoverable. But this is a question that must be left to the geologist to decide.

The extreme views of the early advocates of the theory of an ice age have been to a large extent abandoned. No one now believes in the former existence of a Polar ice cap, and possibly when the irresistible force of ice-dammed rivers has been fully realised, the estimated area of glaciation may be considerably reduced. The so-called great ice age may have been a great snow age, with local centres of glaciation on the higher grounds.

The zoological evidence as to the nature, extent, and duration of the ice age has never been carefully collected. The attention of zoologists has unfortunately been too exclusively devoted to the almost hopeless task of theorising upon the causes of evolution, instead of patiently cataloguing its effects.

There is a mass of evidence bearing directly upon the recent changes in the climate of the Polar Basin to be found in the study of the present geographical distribution of birds. The absence of certain common British forest birds (some of them of circumpolar range sub-generically, if not specifically) from Ireland and the North of Scotland is strong confirmation of the theory that the latter countries were not very long ago outside the limit of forest growth.

The presence of species belonging to Arctic and sub-Arctic genera on many of the South Pacific Islands is strong evidence that they were compelled to emigrate in search of food by some great catastrophe, such as an abnormally heavy snowfall, and the fact that no island contains more than one species is strong evidence that this great catastrophe has only occurred once in recent times. The occurrence of a well-recognised line of migration from Greenland across Iceland, the Faroes, and the British Islands to Europe is strongly suggestive of a recent elevation of the land where the more shallow sea now extends in this locality. The extraordinary similarity of the fauna and flora of the Arctic regions of the Old and New Worlds can only be found elsewhere in continuous areas, and, had it not been for the unfortunate division of the Arctic region into two halves, Palæarctic and Nearctic, would have attracted much more attention than it has hitherto received.

THE RAINFALL

of the Polar Basin is small compared to that with which we are familiar, but its visible effects are enormous. In Arctic Europe and Siberia it is supposed to average about thirteen inches per annum; in Arctic America not more than nine inches. The secret of its power is that about a third of the rainfall descends in the form of snow, which melts with great suddenness.

The stealthy approach of winter on the confines of the Polar Basin is in strong contrast to the catastrophe which accompanies the sudden onrush of summer. One by one the flowers fade, and go to seed if they have been fortunate enough to attract by their brilliancy a bee or other suitable pollen-bearing visitor. The birds gradually collect into flocks, and prepare to wing their way to southern climes. Strange to say, it is the young birds of each species that set the example. They are not many weeks old. They have no personal experience of migration, but Nature has endowed them with an inherited impulse to leave the land of their birth before their parents. Probably they inherit the impulse to migrate without inheriting any knowledge of where their winter quarters are to be found, and by what route they are to be sought. They are sometimes, if not always, accompanied by one or two adults, it may be barren birds, or birds whose eggs or young have been destroyed, and who may therefore get over their autumn moult earlier than usual, or moult slowly as they travel southwards. Of most species the adult males are the next to leave, to be followed perhaps a week later by the adult females. One by one the various migratory species disappear until only the few resident birds are left, and the Arctic forest and tundra resume the silence so conspicuous in winter. As the nights get longer the frosts bring down the leaves from the birch and the larch trees. Summer gently falls asleep, and winter as gently steals a march upon her, with no wind and no snow, until the frost silently lays its iron grip upon the river, which, after a few impotent struggles, yields to its fate. The first and mayhap the second ice is broken up, and when the starrester of the village sallies forth to peg out with rows of birch trees the winter road down the river to the next village for which he is responsible, he has frequently to deviate widely from the direct course in his efforts to choose the smoothest ice and find a channel between the hummocks that continually block the way.

The date upon which winter resumes his sway varies greatly in different localities, and probably the margin between an early and a late season is considerable. In 1876 Captain Wiggins was frozen up in winter quarters on the Yenisei, in latitude $66\frac{1}{2}°$, on October 17. In 1878 Captain Palander was frozen up on the coast 120 miles west of Behring Strait, in latitude $67\frac{3}{4}°$, on September 28.

The sudden arrival of summer on the Arctic Circle appears to occur nearly at the same date in all the great river basins, but the number of recorded observations is so small that the slight variation may possibly be seasonal and not local. The ice on the Mackenzie River is stated by one authority to have broken up on May 13 in latitude 62°, and by another on May 9 in latitude 67°. If the Mackenzie breaks up as fast as the Yenisei—that is to say, at the rate of a degree a day—an assumption which is supported by what little evidence can be found—then the difference between these two seasons would be nine days. My own experience has been that

the ice of the Pechora breaks up ten days before that of the Yenisei, but as I have only witnessed one such event in each valley too much importance must not be attached to the dates.

According to the 'Challenger' tables of isothermal lines the mean temperatures of January and July on the Arctic Circle in the valleys of the Mackenzie and the Yenisei scarcely differ, the summer temperature in each case being about 55° F., and that of winter $-25°$ F., a difference of 80° F.

On the American side of the Polar Basin summer comes almost as suddenly as it does on the Asiatic side, but the change appears to be less of the nature of a catastrophe. The geographical causes which produce this result are the smaller area of the river basins and the less amount of rainfall. There is only one large river which empties itself into the Arctic Ocean on the American side, the Mackenzie, with which may be associated the Saskatchewan, which discharges into Hudson Bay far away to the south. The basin of the Mackenzie is estimated at 590,000 square miles, whilst that of the Yenisei is supposed to be exactly twice that area. The comparative dimensions of the two summer floods are still more diminished by the difference in the quantity of snow.

The snow in the Mackenzie basin is said to be from 2 to 3 feet deep, whilst that in the Yenisei basin is from 5 to 6 feet deep, so that the spring flood in the latter river must be about five times as large as that of the former.

Another feature in which the basin of the Mackenzie differs from those of the rivers in the Arctic regions of the Old World is the number of rapids and lakes contained in it. The ice in the large lakes attains a thickness at least twice as great as that of the rapid stream, and consequently breaks up much later. In the Great Slave Lake the ice attains a depth of 6 to 7 feet, and even in the Athabaska Lake, in latitude 58°, it reaches 4 feet. The rapids between these two lakes extend for 15 miles. The ice on the river breaks up a month before that on the lakes, so that the drainage area of the first summer flood is much restricted.

The arrival of summer in the Arctic regions happens so late that the inexperienced traveller may be excused for sometimes doubting whether it really is going to come at all. When continuous night has become continuous day without any perceptible approach to spring an alpine traveller naturally asks whether he has not reached the limit of perpetual snow. It is true that here and there a few bare patches are to be found on the steepest slopes, where most of the snow has been blown away by the wind, especially if these slopes face the south, where even an Arctic sun has more potency than it has elsewhere. It is also true that small flocks of little birds—at first snow-buntings and mealy redpoles, and later shore larks and Lapland buntings—may be observed to flit from one of these bare places to another looking for seeds or some other kind of food, but after all evidently finding most of it in the droppings of the peasants' horses on the hard snow-covered roads. The appearance of these little birds does not, however, give the same confidence in the eventual coming of summer to the Arctic naturalist as the arrival of the swallow or the cuckoo does to his brethren in sub-Arctic and subtropic climates. The four little birds just mentioned are only gipsy migrants that are perpetually flitting to and fro on the confines of the frost, continually being driven south by snowstorms, but ever ready to take advantage of the slightest thaw to press northwards again to their favourite Arctic home. They are all circumpolar in their distributions, are as common in Siberia as in Lapland, and range across Canada to Alaska as well as to Greenland. In sub-Arctic climates we only see them in winter, so that their appearance does not in the least degree suggest the arrival of summer to the traveller from the south.

The gradual rise in the level of the river inspires no more confidence in the final melting away of the snow and the disruption of the ice which supports it. In Siberia the rivers are so enormous that a rise of 5 or 6 feet is scarcely perceptible. The Yenisei is three miles wide at the Arctic Circle, and as fast as it rises the open water at the margin freezes up again and is soon covered with the drifting snow. During the summer which I spent in the valley of the Yenisei we had 6 feet of snow on the ground until the first of June. To all intents and purposes it was mid-winter, illuminated for the nonce with what amounted

to continuous daylight. The light was a little duller at midnight, but not so much so as during the occasional snowstorms that swept through the forest and drifted up the broad river bed. During the month of May there were a few signs of the possibility of some mitigation of the rigours of winter. Now and then there was a little rain, but it was always followed by frost. If it thawed one day it froze the next, and little or no impression was made on the snow. The most tangible signs of coming summer was an increase in the number of birds, but they were nearly all forest birds, which could enjoy the sunshine in the pines and birches, and which were by no means dependent on the melting away of the snow for their supply of food. Between May 16 and 30 we had more definite evidence of our being within bird flight of bare grass or open water. Migratory flocks of wild geese passed over our winter quarters, but if they were flying north one day they were flying south the next, proving beyond all doubt that their migration was premature. The geese evidently agreed with us that it ought to be summer, but it was as clear to the geese as to us that it really was winter.

We afterwards learnt that during the last ten days of May a tremendous battle had been raging 600 miles as the crow flies to the southward of our position on the Arctic Circle. Summer in league with the sun had been fighting winter and the north wind all along the line, and had been as hopelessly beaten everywhere as we were witnesses that it had been in our part of the river. At length, when the final victory of summer looked the most hopeless, a change was made in the command of the forces. Summer entered into an alliance with the south wind. The sun retired in dudgeon to his tent behind the clouds, mists obscured the landscape, a soft south wind played gently on the snow, which melted under its all-powerful influence like butter upon hot toast, the tide of battle was suddenly turned, the armies of winter soon vanished into thin water and beat a hasty retreat towards the pole. The effect on the great river was magical. Its thick armour of ice cracked with a loud noise like the rattling of thunder, every twenty-four hours it was lifted up a fathom above its former level, broken up, first into ice floes and then into pack ice, and marched down stream at least a hundred miles. Even at this great speed it was more than a fortnight before the last straggling ice-blocks passed our post of observation on the Arctic Circle, but during that time the river had risen 70 feet above its winter level, although it was three miles wide, and we were in the middle of a blazing hot summer, picking flowers of a hundred different kinds, and feasting upon wild ducks' eggs of various species. Birds abounded to an incredible extent. Between May 29 and June 18 I identified sixty-four species which I had not seen before the break up of the ice. Some of them stopped to breed and already had eggs, but many of them followed the retreating ice to the tundra, and we saw them no more until, many weeks afterwards, we had sailed down the river beyond the limit of forest growth.

The victory of the south wind was absolute, but not entirely uninterrupted. Occasionally the winter made a desperate stand against the sudden onrush of summer. The north wind rallied its beaten forces for days together, the clouds and the rain were driven back, and the half-melted snow frozen on the surface. But it was too late; there were many large patches of dark ground which rapidly absorbed the sun's heat; the snow melted under the frozen crust, and its final collapse was as rapid as it was complete.

In the basin of the Yenisei the average thickness of the snow at the end of winter is about 5 feet. The sudden transformation of this immense continent of snow, which lies as gently on the earth as an eider-down quilt upon a bed, into an ocean of water rushing madly down to the sea, tearing everything up that comes into its way, is a gigantic display of power compared with which an earthquake sinks into insignificance. It is difficult to imagine the chaos of water which must have deluged the country before the river beds were worn wide enough and deep enough to carry the water away as quickly as is the case now. If we take the Lower Yenisei as an example it may be possible to form some conception of the work which has already been done. At Yeniseisk the channel is about a mile wide; 800 miles lower down (measuring the windings of the river), at the

village of Kureika, it is about 3 miles wide, and, following the mighty stream for about another 800 miles down to the Brekoffsky Islands, it is nearly 6 miles wide. The depth of the channel varies from 50 to 100 feet above the winter level of the ice. This ice is about 3 feet thick, covered with 6 feet of snow, which becomes flooded shortly before the break up and converted into about 3 feet of ice, white as marble, which lies above the winter blue ice. When the final crash comes this field of thick ice is shatttered like glass. The irresistible force of the flood behind tears it up at an average rate of 4 miles an hour, or about a hundred miles a day, and drives it down to the sea in the form of ice floes and pack ice. Occasionally a narrow part of the channel or a sharp bend of the river causes a temporary check; but the pressure from behind is irresistible, the pack ice is piled into heaps, and the ice floes are doubled up into little mountains, which rapidly freeze together into icebergs, which float off the banks as the water rises. Meanwhile, other ice floes come up behind: some are driven into the forests, where the largest trees are mown down by them like grass, whilst others press on until the barrier gives way, and the waters, suddenly let loose, rush along at double speed, carrying the icebergs with them with irresistible force, the pent-up dam which has accumulated in the rear often covering hundreds of square miles. In very little more than a week the ice on the 800 miles from Yeniseisk to the Kureika is completely broken up, and in little more than another week the second 800 miles from the Kureika to the Brekoffsky Islands is in the same condition.

During the Glacial epoch the annual fight between winter and the sun nearly always ended in the victory of the former. Even now the fight is a very desperate one within the Polar Circle, and is subject to much geographical variation. The sun alone has little or no chance. The armies of winter are clad in white armour, absolutely proof against the sun's darts, which glance harmlessly on six feet of snow. In these high latitudes the angle of incidence is very small, even at mid-day in midsummer. The sun's rays are reflected back into the dry air with as little effect as a shell which strikes obliquely against an armour plate. But the sun does not fight his battle alone. He has allies which, like the arrival of the Prussians on the field of Waterloo, finally determine the issue of the battle in his favour. The tide of victory turns earliest in Norway, although the Scandinavian Fjeld forms a magnificent fortress in which the forces of winter entrench themselves in vain. This fortress looks as impregnable as that on the opposite coast, and would doubtless prove so were it not for the fact that in this part of the Polar Basin the sun has a most potent ally in the Gulf Stream, which soon routs the armies of winter and compels the fortress to capitulate.

The suddenness of the arrival of summer in Siberia is probably largely due to the geographical features of the country. In consequence of the vastness of the area which is drained by the great rivers, and the immense volume of water which they have to carry to the sea, the break up of the ice in their lower valleys precedes, instead of being caused by, the melting of the snow towards the limit of forest growth. The ice on the affluents either breaks up after that on the main river, or is broken up by irresistible currents from it which flow up stream; an anomaly for which the pioneer voyager is seldom prepared; and when the captain has escaped the danger of battling against an attack of pack ice and ice floes from a quarter whence it was entirely unexpected, he may be suddenly called upon to face a second army of more formidable ice floes and pack ice from the great river itself, and if his ship survive the second attack a third danger awaits him in the alternate rise and fall of the tributary as each successive barrier where the ice gets jammed in its march down the main stream below the junction of the river accumulates until the pressure from behind becomes irresistible, when it suddenly gives way. This alternate advance and retreat of the beaten armies of winter continued for about ten days during the battle between summer and winter of which I was a witness in the valley of the Yenisei. On one occasion I calculated that at least 50,000 acres of pack ice and ice floes had been marched up the Kureika. The marvel is what became of it. To all appearance half of it never came back. Some of it no doubt melted away during the ten days' marches and counter-marches,

some drifted away from the river on the flooded places, which are often many square miles in extent, some got lost in the adjoining forests, and was doubtless stranded amongst the trees when the flood subsided, and some was piled up in layers one upon the top of the other, which more or less imperfectly froze together and formed icebergs of various shapes and sizes. Some of the icebergs which we saw going down the main stream were of great size, and as nearly as we could estimate stood from 20 to 30 feet above the surface of the water. These immense blocks appeared to be moving at the rate of from 10 to 20 miles an hour. The grinding together of the sharp edges of the innumerable masses of ice as they were driven down stream by the irresistible pressure from behind produced a shrill rustling sound that could be heard a mile from the river.

The alternate marching of this immense quantity of ice up and down the Kureika was a most curious phenomenon. To see a strong current up stream for many hours is so contrary to all previous experience of the behaviour of rivers that one cannot help feeling continuous astonishment at the novel sight. The monotony which might otherwise have intervened in a ten-days' march-past of ice was continually broken by complete changes in the scene. Sometimes the current was up stream, sometimes it was down, and occasionally there was no current at all. Frequently the pack ice and ice floes were so closely jammed together that there was no apparent difficulty in scrambling across them, and occasionally the river was free from ice for a short time. At other times the river was thinly sprinkled over with ice blocks and little icebergs, which occasionally 'calved' as they travelled on, with much commotion and splashing. The phenomenon technically called 'calving' is curious, and sometimes quite startling. It takes place when a number of scattered ice blocks are quietly floating down stream. All at once a loud splash is heard as a huge lump of ice rises out of the water, evidently from a considerable depth, like a young whale coming up to breathe, noisily beats back the waves that the sudden upheaval has caused, and rocks to and fro for some time before it finally settles down to its floating level. There can be little doubt that what looks like a comparatively small ice block floating innocently along is really the top of a formidable iceberg, the greater part of which is a submerged mass of layers of ice piled one on the top of the other, and in many places very imperfectly frozen together. By some accident, perhaps by grounding on a hidden sandbank, perhaps by the water getting between the layers and thawing the few places where they are frozen together, the bottom layer becomes detached, escapes to the surface, and loudly asserts its commencement of an independent existence with the commotion in the water which generally proclaims the fact that an iceberg has calved.

Finally comes the last march-past of the beaten forces of winter, the ragtag and bobtail of the great Arctic army that comes straggling down the river when the campaign is all over—worn and weather-beaten little icebergs, dirty ice floes that look like floating sandbanks, and straggling pack ice in the last stages of consumption that looks strangely out of place under a burning sun between banks gay with the gayest flowers, amidst the buzz of mosquitoes, the music of song birds, and the harsh cries of gulls, divers, ducks, and sandpipers of various species.

I have been thus diffuse in describing these scenes, in the first place, because they are very grand; in the second place, because they have so important a bearing upon climate, one of the great factors which determine the geographical distribution of animals and plants; and in the third place, because they have never been sufficiently emphasised.

The following Papers were read :—

1. *A Journey across Australia.* *By* GUY BOOTHBY.

Leaving Thursday Island, in Torres Straits, the author and one companion sailed to Townsville. From Townsville they passed by land, through Charters Towers, the Gilberton, Etheridge, and Croydon goldfields, to Normanton, on the Norman River, Gulf of Carpentaria. Here saddle and pack-horses were obtained, stores laid in, and the transcontinental journey to Adelaide commenced. The

route followed was almost due south as far as the Cloncurry mineral fields, thence due east to Hughenden, south-west to Winton, due west to Boulia, only to be driven back again by drought as far as the Thomson River. In a futile attempt to reach the South Australian border at Haddon's Corner, Windorah was reached, but at this stage scarcity of water and horse feed compelled the travellers to abandon their intention, and, after losing two horses from thirst and starvation, to retrace their steps as far as the Barcoo River. This river was eventually followed down, and the Cheviot and Grey ranges crossed to Adavale, where a course was steered along the Bulloo River, and ultimately along the Paroo. Cunnamulla, on the Warrego, was reached, and the river followed down across the Queensland border into New South Wales. Arriving in the town of Bourke, on the Darling River, the remaining horses were disposed of and a rowing boat purchased, in which a distance of 800 miles was traversed to the small town of Menindee, whence a river steamer conveyed them on to Wentworth, whence by the Murray and by train Adelaide was reached, exactly a year and a month after leaving Normanton.

2. *On the Islands of Chiloë.* *By* Mrs. Lilly Grove, *F.R.G.S.*

The Archipelago of Chiloë, lying between 41° and 43° S. lat., is only 25 miles distant from the mainland at its nearest point. The principal island, Chiloë, can be reached by steamer or by one of the native sailing-vessels, which are well managed by the hardy and dexterous 'Chilotes.' These vessels form the chief means of communication, as the postal service is irregular. The island is peaceful and prosperous, and crime is rare among its gentle and hospitable inhabitants. Education is improving. Agriculture and wood-cutting are the chief employments both of men and women. They have few wants; fish and the potato are their main articles of food. Wages are generally paid in kind, often, unfortunately, in alcohol. It is interesting to note that the potato (called *patata* or *papas*) is of Chilian origin, and grows in the wildest districts, even at the top of the highest mountains. A whole region is called after it, and it is sometimes the sole food of the people. Other interesting native plants are the Latué (similar to belladonna), an infusion of which produces temporary madness; the Pangue, valuable as an astringent; the Piñon, rising to a majestic height, with a white resin, also useful medicinally; the Canelo, whose branches are recognised as a flag of truce; and the Alerce, large forests of which are found near Castro and Ancud, and whose wood is most valuable for building purposes; but better means of transport are needed in order to work these forests economically. Fishing is a very important industry, both in Chiloë and the Guaytecas. Telegraphic communication between the last-named islands and the mainland would be of great service, and the Government of Chile should make fishing and shooting regulations to prevent the extermination of the seals, whose skins are prepared near Dalcahué. The chief ports are Ancud and Castro, the latter of which is very picturesque.

3. *On Recent Explorations in Katanga.* *By* E. G. Ravenstein.

A brief account was given of the recent Belgian expeditions to the Katanga country, including the journeys of Delcommune, Captain Stairs, Bia, and Franqui. A summary of the physical geography of the region, its resources and people, was given.

4. *Pictures of Japan.* *By* Professor J. Milne, *F.R.S.*

This paper took the form of an explanation of an important series of lantern photographs illustrating the earthquake phenomena of Japan.

FRIDAY, SEPTEMBER 15.

The following Papers and Reports were read:—

1. *On the Limits between Physical Geography and Geology.*[1] *By* Clements R. Markham, *C.B., F.R.S.*

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2. *On the Relations of Geology to Physical Geography. By* W. Topley, *F.R.S., Geological Survey of England.*

Professor Lapworth in his address to the Geological Section last year at Edinburgh showed clearly the close relationship of geology to physical geography as regards the larger features of the earth's surface—the structure and distribution of mountain chains, the great folds which traverse the earth's crust, and the wider areas of uplift and depression.

I propose to refer mainly to the minor features of the surface, and to show that the nature and 'lie' of the rocks determine these surface features. From this point of view geology forms the basis of physical geography, and a geographer must necessarily be to some extent a geologist.

There is no need to point out that the converse of this is equally true. A geologist who would understand in what way existing geological conditions have been brought about—how strata have been deposited, volcanic rocks erupted, and how denudation has carved the surface into its present shape—must study similar phenomena now in progress.

A comparison of geological and physical maps of any area at once shows that different rock-groups and formations present different types of land, the hills and mountain chains coinciding with the outcrop of certain rocks or strata, whilst other formations are characterised by plains or by lowlands. It is thus clear that the geological structure of any district determines its physical geography. This relation is equally apparent when we compare the structure and surface features in detail. The older masses of rock frequently form mountainous land; the newer Palæozoic and the Secondary rocks occur mainly as a succession of plains and escarpments, each determined by the outcrops of certain beds.

The history of valleys, plains, and gorges can only be understood by reference to their geology. We then see why rivers, after for a while running over wide open plains, suddenly break through hill ranges, cutting the escarpments at right angles, the explanation being that the streams began their work when the whole formed a comparatively even surface, the existing features being due to long-continued erosion.

The escarpments, plains, and transverse river valleys of central and southern England and of eastern France form excellent examples of this structure. Here the geology is simple, a fairly continuous dip in one direction and different beds cropping out beneath each other in definite order.

On the flanks of mountain chains this simple structure does not hold good; there the beds are frequently contorted, inverted, and thrust over each other, so that a superficial reading of the geology would give erroneous results as to the order of succession. But even here the present 'lie' of the beds has determined the physical geography, the disturbances of the rocks having been produced when they were deeply covered by other strata now removed by denudation.

Some igneous rocks weather into conical hills resembling volcanic cones. The same thing often occurs in the weathering of loose sands, whilst sand is frequently blown into conical and crater-shaped hills. A hasty glance at the outward shape of such hills might mislead a traveller. Many conical hills in the south of Scotland are old volcanic vents, up which molten lava once came; but the volcanic cones have been long since removed by denudation, and what we now see are only the

[1] Published in the *Scot. Geog. Mag.*, ix. (1893), pp. 633–638.

once deeply-seated necks of the old volcanoes, the softer parts having been worn away.

Caution is necessary in interpreting the apparent *dip* of strata as a means of determining geological structure; besides folding and inversions, already referred to, we have to guard against being deceived by cleavage, false-bedding, and the fan-shaped structure of mountain chains.

A knowledge of the geological structure of certain rocks in any one area may mislead when applied to distant districts. The soft clays, the limestones, and sandstones of the Jurassic rocks of England are represented in the south and east of Europe by thick masses of limestone, forming prominent mountain ranges; whilst the soft Triassic rocks of England are represented in the Alpine area by huge masses of limestone and dolomite, with intermediate soft bands and with layers of volcanic rock.

Even within so small an area as England we have differences in geological composition, making differences in physical geography. The high and barren moorlands of north-east Yorkshire and the fertile districts of the Cotteswold Hills are both composed of Lower Oolitic rocks: in the former they are sandstones and shales, in the latter they are in great part soft limestones and clays.

The nature of the rock determines the character of the soils and vegetation, the soils being due to the decomposition of the underlying rocks. This is not, however, the case where the solid rocks are covered by drift deposits: here the soils are formed by the decomposition of the drifts.

The sites of early settlements and villages are generally determined by geological surface conditions, water and a dry and fairly fertile soil being required.

The land divisions resulting from these early settlements are in like manner dependent on the physical features, which, however, are not usually the actual boundaries of the parishes, townships, &c.

But where the hills are exceptionally high the summit or the local water parting is often the boundary.

[A discussion followed the reading of these papers, and is printed in full in the 'Geographical Journal' for December 1893, pp. 518–534.]

3. *Report on Scottish Place Names.*—See Reports, p. 554.

4 *Report of the Karakoram Expedition.*—See Reports, p. 564.

5. *On the Influence of Land and Water on the Temperature of the Air. By* J. Y. Buchanan, *F.R.S.*

6. *The Temperature and Density of Sea Water between the Atlantic Ocean and North Sea.*[1] *By* H. N. Dickson, *F.R.S.E.*

At the instance of the Fishery Board for Scotland the author spent the greater part of August 1893, on H.M.S. 'Jackal,' in investigating the distribution of temperature and salinity on the northern and western borders of the continental shelf. Starting from a point fifty-four miles due north of the Shetlands, a line of soundings was run eastwards for about seventy miles in depths of 100 to 200 fathoms, and this was backed by a return line further south in shallower water. A line was next run from the north of the Shetlands to Suderö, Færo Islands, temperatures being observed at depths down to 416 fathoms in the Færo Shetland Channel. From Færo a line of soundings was made to latitude 59° 45′ N., longitude 5° W., whence a due easterly course was made to longitude 1° E. The latter part of the cruise was occupied with a further study of the conditions existing to the east of

[1] A full report will be published in the Annual Report of the Fishery Board for Scotland for 1894.

the Orkneys and Scotland as far south as Aberdeen. The observations, so far as they have been discussed, extend the results obtained by Dr. H. R. Mill to the west of Lewis in 1887; a warm layer, temperature 53° to 56° F., varying in thickness from fifteen to twenty-five fathoms, lies upon the main body of water, the surface of which is some 3° to 4° colder, while its temperature decreases with the depth. At 400 fathoms in the Færo Channel the temperature recorded was 30°·9 F.

7. *The Clyde Sea Area: a Study in Physical Geography. By* HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

This paper deals comprehensively with the results of the investigations carried out by the author for the Scottish Marine Station and the Fishery Board for Scotland on the Clyde Sea Area.

The relations of salinity and temperature throughout the mass of the water are shown to be conditioned almost entirely by the configuration of the various basins of which the Clyde Sea Area is composed.

The influence of water temperature on the air is also discussed, the effects of the Gulf Stream plainly visible at the entrance to the Area being entirely neutralised in its landward reaches.

The complete paper, with numerous illustrations, will be published in the 'Transactions' of the Royal Society of Edinburgh.

8. *Configuration of the English Lakes. By* HUGH ROBERT MILL, *D.Sc., F.R.S.E.*

This is a preliminary note describing the soundings taken by the author and Mr. E. Heawood during June, July, and September, 1893, on Windermere, Ullswater, Coniston Water, Wastwater, Derwentwater, and Bassenthwaite. From the observations made profiles across the lake beds were drawn, and the contour lines of depth laid down on maps. Specimens of the deposits on the floors of the lakes were collected, and will be described. This is the only systematic survey of the lakes made with a view to delineating the configuration of the basins, and the work will be utilised on the Ordnance Survey maps as soon as it has been fully discussed.

The complete discussion will be presented to the Royal Geographical Society.

SATURDAY, SEPTEMBER 16.

This Section did not meet.

[Paintings made during a voyage to the Antarctic regions by Mr. W. G. Burn Murdoch were exhibited in the Section Room from 11 A.M. to 1 P.M.]

MONDAY, SEPTEMBER 18.

The following Reports and Papers were read:—

1. *Report of the Committee on the Exploration of Ancient Remains in Abyssinia.*—See Reports, p. 557.

2. *Report of the Committee on the Climatological and Hydrographical Conditions of Tropical Africa.*—See Reports, p. 572.

3. *On Uganda and its People.* *By* Captain WILLIAMS, *R.A.*

This paper was a study of the people of Uganda with regard to their physique, industries, customs, and mode of government.

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4. *On Hausa Pilgrimages from the Western Sudan.*[1] *By* Rev. CHARLES H. ROBINSON, *M.A.*

Mr. Robinson began by explaining the sources from which the facts referred to in his paper were derived. He had just returned from a preliminary journey along part of the north border of the Sahara, which had been made with a view to ascertain the possibility of crossing the Great Sahara from Tripoli in order to visit the Hausa States which lie to the west of Lake Chad, and to the north of the rivers Niger and Binue. This journey he proposes to attempt during the coming year.

His intercourse with Hausa-speaking natives in North Africa served to reveal the enormous extent to which the pilgrimage to Mecca is affecting the life and habits of the people in the far interior. Many thousands of pilgrims find their way thence to Mecca, some by crossing the Great Sahara, and going by sea from Tripoli, others by way of Wadai, Darfur, Khartum, and Suakim. He read an account given by a Hausa pilgrim of the capture of Khartum and the death of General Gordon.

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5. *On the Relation of Lake Tanganyika and the Congo.* *By* J. HOWARD REID.

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6. *On Environment in relation to the Native Tribes of the Congo Basin.* *By* HERBERT WARD.

Throughout the vast and densely populated area of the Congo basin the native tribes are without history and without a written language. The tribal characteristics and the mental condition of the natives differ widely in tribes inhabiting different localities. It is an accepted fact that the Congo population is allied to the Great Bantu group, one of the most extensive of the African racial divisions, and it is but natural to infer that the phenomena of environment represent the main element of influence to which these variations of character are to be attributed. The tribes of the Lower Congo, which is a well-favoured country, with fertile soil and well-defined seasons, are represented as being mild, peaceful, and superstitious. The tribes of the Upper Congo, who reside in the great forest swamp, a region where all is sunless gloom and damp decay, where torrential rains and the tropical sun produce a fermenting hotbed of exuberant foliage, are, on the other hand, typical savages, indulging in cannibalism and waging perpetual petty warfare upon their neighbours. It would appear obvious that the Bantu tribes, now inhabiting this great forest country through which the Upper Congo River and its affluents flow, have degenerated, through stress of unfavourable environment, since the unknown time when the various tribes of this race travelled towards the south and the west.

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7. *On the Vertical Relief of Africa.* *By* Dr. H. G. SCHLICHTER.

The author submitted a series of ten sections of the vertical relief of Northern and Central Africa. These sections were drawn from east to west at intervals of 4° of latitude northward from 8° S. The vertical scale is exaggerated eighty times compared with the horizontal. These sections are of value, not only in showing the relations of vertical relief, but also in indicating by dotted lines the regions where observations are wanting; they vividly present the gaps which remain in our knowledge of the configuration of Africa.

[1] Published in the *Geog. Journ.*, ii. (1893), pp. 451-454.

Disease	Morocco	Algeria	Tunis	Tripoli and Barca	Egypt	Sahara	Senegal	Sierra Leone	Gold Coast	Niger Delta	Bight of Biafra	Congo	Cape Colony	Natal and Zululand	Transvaal	Bechuanaland	East Coast	South and East Central Region	Abyssinia
Malaria	*	**	**	*	*	*	***	***	***	***	**	***	*	*	*	*	***	**	*
Typhoid fever	*	***	*	—	**	—	*	*	—	—	*	—	**	**	**	*	*	**	**
Typhus	*	*	—	*	—	—	—	—	—	—	—	—	?	—	—	—	—	—	—
Relapsing	*	*	—	—	**	—	—	—	—	—	—	—	—	—	*	—	—	—	*
Cholera	*	**	*	*	*	—	*	—	—	—	—	—	—	—	—	—	*	—	*
Dysentery	**	***	**	?	***	—	***	**	*	***	**	*	**	**	**	**	***	*	**
Diarrhœa	**	***	**	—	—	—	***	**	—	***	**	—	**	**	**	**	***	*	**
Smallpox	**	**	*	—	**	—	***	—	**	—	—	—	*	*	—	*	***	*	**
Scarlet fever	—	—	*	—	*	—	—	—	—	—	—	—	—	*	—	*	—	—	—
Measles	—	**	*	—	*	—	**	—	—	—	—	*	—	*	—	*	*	*	—
Phthisis	*	*	*	—	*	*	*	—	*	—	**	**	**	*	*	—	*	*	*
Respiratory	*	**	*	—	*	—	—	**	—	***	—	**	*	*	—	*	*	**	**
Leprosy	***	***	***	—	***	—	**	*	**	*	*	*	*	—	*	—	—	—	—
Acute rheumatism	*	*	***	—	***	—	***	—	*	—	***	**	—	—	—	*	—	*	**
Chronic rheumatism	**	—	***	—	***	—	***	—	**	—	—	—	***	—	—	**	—	—	***
Syphilis	***	*	***	—	***	—	***	—	***	—	—	—	**	—	—	—	—	**	***
Ophthalmia	***	—	—	—	***	—	—	—	—	—	—	—	—	—	—	**	***	**	***
Hepatitis	—	**	*	—	**	—	**	—	—	*	—	**	—	—	—	***	—	***	—
Abscess of liver	*	**	*	—	**	—	**	*	*	*	*	*	—	—	—	*	**	*	—
Aleppo boil	**	***	**	—	*	—	—	—	—	—	—	—	—	—	—	—	—	*	—
Goitre	—	*	—	—	—	—	—	—	—	—	*	—	—	—	—	—	—	—	—
Diphtheria	—	—	**	—	—	—	—	—	—	—	—	—	—	**	**	—	*	—	—
Plague	*	*	*	*	*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dengue	—	—	—	*	*	—	**	—	—	—	—	—	—	—	—	—	**	*	—
Yellow fever	—	—	—	—	—	—	**	***	**	*	—	—	—	—	—	—	—	—	—
Filaria	—	—	—	—	**	—	—	—	—	—	—	*	—	—	—	—	—	*	—
Yaws	—	—	—	—	—	—	*	**	***	*	*	***	—	—	—	—	—	—	—
Beri-beri	—	—	—	—	—	—	—	**	*	—	**	***	—	—	—	*	—	—	—
Elephantiasis	**	—	—	—	*	—	*	*	**	*	—	—	—	—	—	—	**	**	—
Guinea-worm	—	—	—	—	**	—	**	*	*	**	—	*	—	—	—	—	—	—	—
Egyptian chlorosis	—	—	—	—	***	—	—	—	—	—	—	**	—	—	—	—	—	—	—

8. *The Distribution of Disease in Africa.* *By* R. W. Felkin, *M.D., F.R.S.E., &c.*

There are not many maps existent which show at a glance the distribution of disease in any country. An attempt is made in the map shown by the author to illustrate the grouping of the principal diseases occurring in Africa, so that not only the existence of the disease may be seen, but its comparative prevalence or severity appreciated. This is done by using a symbol for each disease dealt with, which appears at those districts where the disease exists. The symbol is doubled if the disease is very prevalent, and in cases where it is exceedingly severe three symbols are placed together. The climatology of various areas has also been introduced, and if this map is referred to one showing the altitude, it is comparatively easy to see why different diseases should be present or absent in any given region.

On looking at the map it can at once be noted that there are three distinct areas in Africa in which the distribution of malaria is widely different. It is most intense at the coastal regions and the long banks of the great rivers, it decreases with altitude and, as will be noticed, it does not obtain at all after a certain altitude, over 3,500 feet. It is not found in the Sahara, as will be at once seen, except in isolated areas; again, in the extreme south of the continent it is at once apparent how altitude and climatology limit its production.

The distribution of phthisis is also seen at a glance to be limited in its incidence by altitude and climatology, and probably also to a certain extent by malaria, for where malaria is most severe phthisis hardly if ever occurs. Again we notice that diarrhœa and dysentery are most frequent in those places where malaria is chiefly met with, showing generally that the climatological factors producing the one disease markedly influence the incidence of the others.

It is impossible to give briefly further details with regard to the paper in any other way than in tabular form. In the table, p. 838, where one * appears the disease is present, where two appear it is very prevalent, and where there are three it is exceedingly severe.

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9. *Middle Egypt from Ptolemaic Maps and Recent Surveys.* *By* Cope Whitehouse, *M.A., F.R.A.S.*

The question whether the maps which accompany the text of Cl. Ptolemy, A.D. 150, were copied from originals extant in the eleventh century, or were draughted by the copyists of the manuscripts, by plotting the positions given in the text, is of great importance. If there were original maps, contemporary with the Alexandrian geographer, or not later than the fifth century, then these copies furnish independent and trustworthy information as to those facts stated on them which are not found in Ptolemy's lists of positions. This view has been maintained by the author of this paper since 1882.

The map of Middle Egypt, 1892, by the Ministry of Public Works, Cairo, and the line of levels given by Major Brown, 'The Fayoum and Lake Mœris' (1892), run under his direction by Messrs. Joseph and Pini, furnish a crucial test. The section of fifty-two miles from Beni-Suef to the furthest trace of habitation in the N.W. Fayoum is nowhere above the level of the Nile, except in crossing the promontory of Dimeh—the island-pyramid in Mœris of Herodotus and Diodorus. It would be an island if the water in the Fayoum stood at the level of + 6 metres; high Nile being taken at about + 30, and the present Birket el-Kerun at − 48 metres.

Noting the successive changes through which this region passed, as shown by its physical conditions, history, and archæological remains, it may be established with certainty that the positions of the places mentioned by Cl. Ptolemy could not have been plotted on a map of the middle ages, nor on a map of ancient Egypt, reconstructed from the historical and geographical data of Herodotus (B.C. 454), Diodorus (B.C. 20), or Strabo (B.C. 24). Such attempted reconstructions by Linant and others were shown; and the differences between them and Ptolemaic maps

from manuscripts in Mount Athos, the Vatican, Milan, and Venice, and of Chrysanthus and Berlinghieri, and from the printed editions of Cl. Ptolemy, were pointed out. The maps of Cl. Ptolemy represent his positions plotted upon a region whose relative areas of land and water only existed, as depicted, after the middle of the first century, and before the end of the third, of our era. The paper was further illustrated by views on the line from Beni-Suef to that Temple, north of Dimeh, whose existence was first pointed out by the author of this paper in 1882.

The conclusion is that some, at least, of the maps accompanying the text of Cl. Ptolemy in mediæval manuscripts are copies, more or less faithful, of maps drawn not later than the end of the third century, and that they are probably contemporaneous with the Alexandrian geographer's text, A.D. 150.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *Notes of an Antarctic Voyage. By* WM. S. BRUCE.

After a boisterous passage of over a hundred days on the steam whaler 'Balæna,' from Dundee, we met the first iceberg on December 16, 1892, in 59° 40′ S., 51° 17′ W. We continued in a more or less southerly course, passing to the east of Clarence Island. Danger Islets were sighted and passed on December 23, and on Christmas Eve we were in the position Ross occupied on New Year's Day, 1843. Until the middle of February we remained roughly between 62° S. and 64° 40′ S. and 52° and 57° W., the western limit being Terre Louis Philippe and Joinville Island.

All the land seen was entirely snowclad except on the steepest slopes, which were of black, apparently igneous, rocks. The few specimens of rocks obtained from the ice and from the stomachs of penguins bear this out; Professor James Geikie finding olivine, basalt, basalt lava, and possibly gabbro among them. Rock fragments and earthy matter were seen on some of the bergs and ice. On January 12 we saw what *appeared to be* high mountainous land and glaciers stretching from about 54° 25′ S., 59° 10′ W. to about 65° 30′ S., 58° 0′ W., and which I believe may have been the eastern coast of Graham's Land, which has not been seen before.

The whole of this district south of 60° S. is strewn with bergs, and south of 62° S. they become very numerous. No entire day can be recorded when bergs were not seen; as many as 65, all of great size, to say nothing of smaller ones, were counted at one time from deck. The longest we met was about 30 miles long, one was about 10 miles long, and several from 1 to 4 miles in length. The highest the 'Balæna' sighted could not have been over 250 feet high, and many were not over 70 to 80 feet high. All the bergs were tabular, or weather-worn varieties of that form. The base of the bergs was coloured brown by marine organisms.

The pack ice is said not to be heavier than that of the north, and is similar in nature. It is frequently coloured brown by *Corythron criophyllum*, a very abundant diatom. We first met pack ice, on December 19, in 62° 20′ S., 52° 20′ W.; it was dense, and ran east and west. In January we met the pack edge running east and west in 64° 37′ S. from about 54° to 56° W.

A few observations for the freezing- and melting-point of ice were made, and some sea-temperatures recorded. The lead was cast in the vicinity of Danger Islets and some bottom samples obtained, the depth varying from 70 to over 300 fathoms.

Periods of fine calm weather alternated with very severe gales, usually accompanied by fog and snow. The lowest air temperature recorded was 20°·8 F. on February 17, and the highest 37°·60 F. on January 15. December showed an average of 31°·14 F., January 31°·10 F., and February 29°·65 F. The barometer never rose above 29·804 inches.

No whale resembling *Balæna mysticetus, i.e.*, the Bowhead or Greenland black whale, was seen; but many finbacks, some hunchbacks, bottlenoses, grampuses, and several kinds of seals, the hunting of which in default of whales was the object of the voyage.

2. *On the Antarctic Expedition of* 1892–93. *By* C. W. DONALD, *M.B.*

Originally proposed as a commercial undertaking, the object of which was to discover a true whalebone whale living under similar conditions to the black or Greenland whale of the north, the idea of combining with it some scientific research originated with the Royal Geographical Society. We made the ice on December 18, sighting the South Shetlands on the same day. The bergs differ greatly from those of the north, being flat-topped and having perpendicular cliffs. This characteristic shape I believe to be due to the conformation of the land, which is almost wholly of a volcanic nature. On Christmas Day we lay anchored to an ice floe in lat. 64° 23′ S., long. 56° 14′ W. The scenery was marvellous. From our position on that day the mountains of Palmer's Land lay to the west, culminating in the peak of Mount Haddington (7,050 feet). The ice floe stretched to the south as far as the eye could reach. To the east lay a long chain of bergs, their perpendicular faces tinged a bright red by the low sun; to the north, the loose scattered ice, small bergs, and dark water channels through which we had just steamed. We discovered a channel running from east to west through Joinville Island, cutting off its southern portion as a separate island, which our captain called Dundee Island. Along the shores of this channel were four penguin rookeries, two of which were visited. Near the southern shore lies a sunken reef on which we had the misfortune to run aground. Happily we got off without accident. A number of geological specimens, fossils, and photographs were obtained. We arrived at Dundee early in June, having been absent a little over nine months.

3. *On the Importance of Antarctic Exploration.* *By* Admiral Sir ERASMUS OMMANNEY.

4. *Recent Exploration in Tibet.* *By* E. DELMAR MORGAN.

While the general features of Tibet have been known from very early times it has been reserved for modern explorers to acquaint us more closely with the leading characteristics of this marvellous region. Especially is this the case with the northern and central parts of this country, left blank on our maps. The list of these explorations begins with the Brothers Schlagintweit and ends with Captain Bower and Dr. Thorold's and Mr. Rockhill's recent journeys. Their discoveries have opened out new fields of research in hitherto inaccessible parts. They have ascertained the continuity of the Kuen Luen system through twenty degrees of longitude, and made known the direction and structure of its principal chains. They have shown the lacustrine character of the central plateaus, and traced almost to their sources some of the mightiest rivers of Asia. They have thrown light on the climatic conditions of these lofty deserts, and seen an extraordinary abundance of animal life on them. Their researches have proved the existence in former times of a line of flourishing oases along the northern foot of the Kuen Luen, by which the Chinese silk trade passed in the middle ages, and have brought to light the rich gold-fields of Northern Tibet. The leading features of this *terra incognita* are well described in Captain Bower's diary, and the whole subject of Tibetan exploration has been treated in the most thorough and admirable manner by M. Dutreuil de Rhins in his 'Asie Centrale.'

5. *On the Bengal Duars.* *By* EDWARD HEAWOOD, *M.A.*, *F.R.G.S.*

The term 'Duars' is applied to a tract of country lying along the foot of the Himalayas of Bhután, and including the 'doors' or passes into that country. The first ranges here rise like a wall, wooded to their summits, from an undulating

plain of slight elevation, which embraces a strip of forest-clad 'Terai' and a more open country further south. Over a great part savannahs of gigantic grass alternate with patches of forest, sál on the higher and lighter soils, and mixed forest fringing the streams. The grass is burnt down annually, and the trees with which it is dotted are usually quick growing and shed their leaves annually, and are thus less affected by the burnings. The tiger, leopard, bear, elephant, rhinoceros, buffalo, bison (so called), pig, and several kinds of deer inhabit the jungles. The peacock, jungle-fowl, florikan, parrots, and a handsome pigeon are the most prominent birds. The rainfall is very great, and the climate unhealthy, though this improves with clearing. The tract is sparsely inhabited, except in the southern and newly-settled parts, by Mechs, a tribe of Mongolian affinities who can thrive in spite of the malaria. They are of wandering habits, cultivating by burning patches of jungle, and moving on to new spots after a few years. Much of the land is very fertile, and well suited for both early and late rice crops. Channels, often of great length, are dug by the Mechs from the numerous streams for the irrigation of the late rice crops, though the tendency of the rivers to deepen their beds in the friable soil is a difficulty to more permanent settlers. The climate and the exposure to raids from Bhután have kept the country in a backward state. It became British territory as a result of the war of 1864. Much land has since then been settled and tea-gardens opened, especially in the western part; while within the last three years a large tract of jungle has been provisionally set apart by Government—at the instance of the Rev. A. J. Shields, C.M.S. missionary to the Santals, warmly supported by Mr. D. Sunder, settlement officer at Jalpiguri—for settlement by Santals, who in their hill country south of the Ganges are often unable to obtain sufficient land for cultivation. Forty families were taken up in 1891, the author assisting in their settlement, and still larger numbers have followed since. Although the partial failure of the rains in the first season caused unforeseen difficulties at first, these, it is hoped, are now in a fair way to be overcome. It should be mentioned that a similar experiment has been tried with success in Assam by a Norwegian mission.

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6. *The Use of the Lantern in Geographical Teaching.* *By* B. Bentham Dickenson, *M.A.*

There has been for some years past a growing conviction amongst teachers that they have in the optical lantern a very important auxiliary. In the hope that by united action much valuable time might be saved, a meeting of public schoolmasters was held at Oxford in May of this year, at the invitation of Mr. H. J. Mackinder.

At this meeting an association for the promotion of geographical teaching was formed and some of its functions discussed. It was hoped that it might 'serve as a medium for disseminating ideas and suggestions for improved methods of teaching geography,' 'that it might approach examining bodies with a view to pointing out how greatly many of the examination papers set lead to keeping the subject at the "cram" level,' that it would naturally take in hand the management and preparation of geographical lantern-slides, and in time, perhaps, arrange for geographical museums.

It was agreed that, for the present, the work of the association should be limited to the preparation of lantern-slides for such schools as might wish to use the optical lantern in class teaching.

At a subsequent meeting held in August at University College School, London, a method of teaching by lantern-slides was discussed, and the character of the slides to be prepared determined.

The object of this paper is to bring the newly formed association under the notice of those interested in the teaching of geography, to give some account of the work upon which it is now engaged, and to exhibit a few of the slides prepared under its auspices.

Section F.—ECONOMIC SCIENCE AND STATISTICS.

President of the Section—Professor J. Shield Nicholson, M.A.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

The Reaction in favour of the Classical Political Economy.

It may naturally be expected in the address which, as President of this Section, I have the honour to deliver that some attempt should be made at originality, or at any rate at novelty. Accordingly, I hope that I shall fall in with the traditions of my office by defending a series of paradoxes and by running counter to a variety of popular opinions. I will only premise that however paradoxical I may appear, and however much I may seem to strain at singularity, I shall speak always to the best of my ability with the utmost good faith, and I shall endeavour to give only the results of my most deliberate convictions.

The central paradox which I propose to defend—the root of the whole series—is that the so-called orthodox, or classical, political economy, so far from being dead, is in full vigour, and that there is every sign of a marked reaction in favour of its principles and methods. The singularity of my position may be indicated by a word and a phrase. The word is Saturn, the phrase 'we are all socialists now.' I shall try to show that the traditional English political economy has neither been banished to Saturn nor stifled by socialism, and that in fact it is stronger than ever. This renewed vigour is no doubt largely due to the attacks made upon it on all sides in increasing force for the last twenty years. The dogmatic slumber induced by popular approval has been rudely shattered, and although some of the more timid followers of the orthodox camp thought they had been killed when they were only frightened and awakened, the central positions are more secure than before.

Consider, in the first place, the question of scientific method and the closely allied question of the relation of political economy to allied sciences. The method practically adopted by Adam Smith and Ricardo, and reduced to scientific form by Mill and Cairnes, and quite recently and still more effectively by Dr. Keynes, must still be regarded as fundamental. It has survived and been strengthened by two distinct attacks. In the first place, the extreme advocates of the historical method attempted to reduce political economy to a branch of history and statistics. They were concerned to pile up facts and add up figures, and they seemed to think that no guiding principles were necessary. But compilations of this kind are, properly speaking, not even history, still less are they political economy. History does not consist simply in collecting facts; the facts must be grouped, arranged, and connected in an orderly manner. A room-full of old newspapers is not history, though it may contain much material for history. There was really nothing new in this extreme form of the historical method. It was a reversion to a primitive type. The plan had been adopted by chroniclers time out of mind; they embedded facts, signs,

wonders, and traditions, as the mud of a river embeds what happens to fall in it. The facts are the fossils of the historian, and he has to make a very few go a long way. In economic literature we have an example of this method in the 'Annals of Commerce' of Anderson and Macpherson. The simple device is to collect all the facts and opinions about Commerce all the world over, and arrange them under the year in which they happened. The basis of classification is time pure and simple, and at the best we have an imperfect collection of materials which must be sifted and weighed to be of any service.

Now compare this method of simple accumulation—this attempt to write a biography of Father Time as a man of business—with the historical method adopted by Adam Smith; at least two-thirds of the 'Wealth of Nations' is history, and it is history of the first rank, and it is so because it is history that is introduced for the illustration, confirmation, or qualification, as the case may be, of principles. It does not follow because the principles are fundamental that the facts are warped and distorted; it simply means that the facts are made intelligible. Take, for example, his account of the economic aspects of the feudal system. He brushes away the technicalities and looks into the inner life as easily as William the Conqueror at the Council of Salisbury. Or, to take a modern instance, he is like a naturalist who puts aside the parts of the creature he does not want in order that he may see what he does want more clearly. This is a very different matter from suppressing truth and warping facts to suit preconceived opinions. It is needless to say that Adam Smith made some mistakes, *e.g.*, in the treatment of the mercantilists; it ought to be equally needless to say that he made some remarkable discoveries of the processes of economic development. Adam Smith also made large use of the comparative method; he literally ranged from China to Peru in his survey of mankind. What is the underlying assumption in this procedure? It is simply that in economic affairs, in matters of buying and selling in the widest sense of the terms, in satisfying wants by labour, in the accumulation of wealth, there are certain characteristics of human nature that may be regarded as fundamental. These are no doubt subject to modifications by other influences, but modification is not total suppression or eradication. How long would it take the Ethiopian to change his skin under a different climate? And is it not proverbial that human nature is more than skin-deep? I think the Ethiopian might become very pale in complexion long before he would learn to prefer low wages to high wages, and much labour to little labour. Economists may learn something from the poets. Why do the creations of the greatest poets live and move? Why do we assent at once to their reality? Simply because they are like ourselves, and we feel with Goethe that we ourselves could commit the same crimes in debasement, and achieve the same glory in exaltation, of spirit. The gods and goddesses, the sylphs and fairies, are only shadows. Can any man read Shakespeare or Homer—to say nothing of undoubted historical records—and deny that a large part of human nature, especially that part with which economists have to deal, is subject to but little variation? Knowledge grows and is handed on from age to age, and the power of man over nature steadily increases, but the feelings are renewed with every generation. The children of the nineteenth century may be precocious and priggish, but they are not nineteen centuries old. Let me remind you, though I am anticipating my argument, that the latest and most advanced scientific economics—that which the Austrian economists have evolved out of the conception of utility—in reality lays more stress than Adam Smith did on the universality of the feelings of mankind. The only difference is that he knew that he was speaking plain prose, and they sometimes think they are only speaking subjective philosophy. In consequence, Adam Smith's men and women are more real and less uniform than the offspring of the new analysis. But the point of importance is the recognition of certain characteristics of human nature as fundamental; there is no other justification for the use of the comparative and historical methods in the broad manner of Adam Smith.

There are, however, still evidences in recent writers of the influence of that narrow view of history which tries to avoid principles, in order to make an impressionist record of facts. Impressionism may be good art, but it is bad science. Too much stress, for example, is laid on the mere enumeration of statutes and preambles,

and too little attention is given to the far more difficult question, How far was the law operative, and how far was the preamble a just description? But signs are not wanting that the broader method of Adam Smith is gaining ground. The work of Mr. Seebohm on the 'English Village Community' is a splendid example, worthy to be placed on a level with the best chapters of the 'Wealth of Nations'; and Dr. Cunningham throughout his excellent history has informed facts with principles.

But it is time to observe that the traditional method of English political economy was more recently attacked, or rather warped, in another direction. The hypothetical or deductive side was pushed to an extreme by the adoption of mathematical devices. I have nothing to say against the use of mathematics, provided always that the essential character of mathematics is borne in mind. Mathematics is a formal science that must get its materials from other sciences. It is essentially as formal as formal logic. The mathematician is an architect who must be provided with stones and wood and labour by the contractor. It is one thing to draw a plan, another to erect a building. In economics there are certain relations which are most easily expressed in mathematical form. One of my greatest obligations to Professor Marshall is that when I began the study of political economy at Cambridge, some twenty years ago, he advised me to read Cournot. And before going further I should like to say that I think one of the greatest signs of power in Professor Marshall's 'Principles' is that he has transferred his mathematical researches and illustrations to appendices and foot-notes, and in his preface also he has admirably stated the limits and functions of mathematics in economic reasoning. I also gladly avail myself of this opportunity of expressing my concurrence with the views of Professor Edgeworth in his excellent address on this topic as President of this Section in 1889. But less able mathematicians have had less restraint and less insight; they have mistaken form for substance, and the expansion of a series of hypotheses for the linking together of a series of facts. This appears to me to be especially true of the mathematical theory of utility. I venture to think that a large part of it will have to be abandoned. It savours too much of the domestic hearth and the desert island. I announced my intention at the beginning of running counter to some popular opinions. I ask for your patience and forbearance when I say that in my opinion the value of the work of Jevons as regards the main body of economic doctrine has been much exaggerated. I am ready to admit that much of his work in finance and currency and in many special problems is excellent. But he was, I think, too deficient in philosophical grasp and intellectual sympathy to give the proper place to a new conception: witness his treatment of Mill and Ricardo. Again, Jevons was not a mathematician of the first rank; he struggles with the differential calculus as a good man struggles with adversity. The older economists maintained that price was the measure, not of utility, but of value, and value could not be reduced simply to utility. Things, they said, might have a high value in use and but little value in exchange. Jevons, by making the distinction between final and total utility, thought that he had discovered a method by which utility might be measured by price. No doubt, if we make adequate hypotheses, qualifications, and explanations this may be done; and, in the same way, if we introduce enough cycles and epicycles we may explain or describe the motions of the stars. But price is essentially the expression of objective and not of subjective relations—that is the older view in modern phraseology; the attempt to make a kind of pre-established harmony between the two leads to unreality. Price depends upon demand and supply, and the degree of utility is one element affecting demand. In my view the distinction between final and total utility is of qualitative importance; it is of service in explaining the real advantage of exchange; although the essential character of this advantage has been explained by Adam Smith and his successors. The precision of the new phraseology, especially when translated into curves, gives definiteness and sharpness to the conceptions. The subject is too intricate for more detailed consideration in this place. I will only add that in my view Professor Marshall's criticism of Jevons may be carried much further, with a still further rehabilitation of Ricardo.

There is another direction in which I think the mathematical economists have wandered far from reality. I allude to the stress laid upon what are called marginal increments. There is a tendency to magnify the effects of the last portion of supply or the last expression of demand. I will only say that this doctrine is very apt to run into the fallacy which may be popularly described as the tail of the dog fallacy—the idea being that the tail wags the dog and the tip of the tail wags the tail.

To resume in a sentence: the method of the so-called orthodox English economists has only been modified and supplemented, not revolutionised and supplanted, by the historical and mathematical methods of recent writers, and this, in my opinion, is being recognised more and more.

I pass on to consider a closely allied question—the question, namely, of the limitation of the boundaries of the subject-matter of political economy. In my view one of the greatest merits of the orthodox economists was the careful distinction they drew between economic and other social sciences. They refused to merge it in the misty regions of general sociology, and they excluded from its borders the rocks and quicksands as well as the green pastures of ethics and religions. This specialisation, they argued, was necessary if any real advance was to be made beyond the expression of platitudes and sentiments. They allowed that in practical social problems there were in general other considerations besides the purely economic; but these they left to the jurist, the moralist, or the politician. For a time, however, especially under German influences, attempts were made to break down these boundaries, and the economist was elevated to the position of universal philanthropist and general provider of panaceas. Mill himself was partly to blame for the excursions which he made into the applications of social philosophy to practice. It is to these excursions we are indebted for the fantastical notion of the unearned increment, and the curious idea that it is the duty of people to leave the bulk of their money to the State, or rather the duty of the State to take it. Fortunately, however, for the progress of economics, this ideal of breadth without depth has not become dominant, and any force it had is already spent. The advances made in other social or less vaguely human sciences have been so great that the economist is obliged to exclude them from his domain.

Still to some extent the view prevails, especially in Germany, that it is the business of the economist to discover the general conditions of social well-being, and to show how they may be realised. If such an attempt were seriously made it could only end in the projection of the personality of the writer into an ideal, and one ideal would succeed another like a set of dissolving views. Suppose, for example, that I personally were to attempt to set up an ideal, and, not having imagination enough to create a new one, I were to turn to ancient Greece. There is something very fascinating about the life of the typical Athenian in the best days of Athens. Physical beauty and vigour were considered as essential as keenness of intellect, appreciation of the fine arts, and skill in oratory; and this intense self-realisation was tempered by ardent patriotism and a strong sense of the duties of citizenship. The principal blot, from the modern point of view, was the institution of slavery and the relegation of most industrial functions to slaves. I might as an economist, if this breadth of view were justified, take it on myself to show how modern life might be Hellenised, and by leaving out slavery and introducing a little Christian charity a very pleasing ideal might be made, and then I might go on to show what steps Government should take to realise this ideal.

In the meantime, however, my friend Dr. Cunningham might take as his type one of the equally fascinating religious communities of the Middle Ages, and, by leaving out some of the superstitions and inserting a few Hegelian contradictions, he might construct an equally attractive ideal and proceed to direct the statesmen how it might be carried into practice. But when all the other economists had worked out similar projects—Professor Sidgwick, for example, on the lines of Bentham, and Professor Edgeworth, with his love of measurements, on the lines of Pythagoras—the difficulty would arise, Who was to be the ultimate arbiter? And to this question no one would accept the answer of the rest.

Perhaps it may seem that my illustration goes beyond the argument; let me,

then, state the position in general terms. According to the traditional English view it is not the business of the economist to decide all the disputes that may arise even regarding fundamental questions in ethics, religion, fine art, education, public law, administration—to decide, in a word, the first duty of man and the last duty of Governments. His sphere is much more limited, and the limits have been indicated with tolerable precision by the classical English economists. Even in England, however, there has been a tendency in recent years to remove the old landmarks, and I do not mean simply on the part of socialists, but by those who in the main profess to accept the English traditions.

Just as the German idealists think it is the business of the economist to discover the way to the perfectibility of the species, the English realists impose upon him the duty of finding the road to the greatest happiness of the greatest number. In technical language political economy is the economy of utility. No doubt, at first sight, this aim seems to be both definite and practical. From the old inquiry, 'How nations are made wealthy,' to the new inquiry, 'How nations are made happy,' it seems a natural and easy transition. For the essence of wealth is to possess utility, to satisfy desires, to create happiness. It is obvious also that the happiness of a people depends largely on its economic conditions in the narrowest sense of the term; it depends, that is to say, on the amount and distribution of its material wealth. Accordingly it seems plausible to maintain that the economist ought to discover by his calculus of utility those principles of production and distribution that will lead to most happiness.

Plausible and natural, however, as this transition from wealth to happiness may seem, it may readily lead to the abandonment of the central position of the classical economists. The steps are worth tracing. The first deduction made from the general principle of utility is that it obeys a law of diminishing return. Every additional portion consumed or acquired of any commodity gives a decreasing satisfaction, and passing through the point of satiety we reach the negative utility of being a nuisance. Illustrated by the usual curve this law assumes the character of a mathematical axiom.

The next step is to show that the rich man derives very little utility (or happiness) from his superfluity, whilst if his abundance were divided amongst the poor a great amount of happiness would be created. It seems to follow at once that, assuming an average capacity for happiness, the more equal the distribution of wealth the greater will be the happiness of the people. Never did any theory of equality assume such a simple and scientific form; it is like the advent of primitive Christianity in the guise of a new philosophy.

The practical question remains, 'How is this ideal to be carried out?' Obviously it is too much to expect that the principle of natural liberty and the policy of *laisser-faire* may be left to work out this latter-day salvation. Competition may be well enough for the strong, but is the destruction of the poor and weak. Accordingly it seems easy to prove, or at least to presume, that great powers must be given to the State. It only remains to bring in the principle which Mill flattered himself was his chief contribution to economic theory, viz., that the distribution of wealth depends entirely on the opinions of mankind, that these opinions are indefinitely pliable, and that, therefore, no schemes of distribution can be called impracticable, and we arrive at the conclusion of the whole matter. And practically that conclusion is nothing less than State Socialism.

It needs no demonstration, however, that nothing could be more opposed to the traditional English political economy. What, then, becomes of my contention that it remains unshaken, and that there are signs of a strong reaction in its favour? The truth is that this conclusion has again brought into prominence other portions of the old doctrine that had been allowed to fall into the background. We are confronted with the limited power of the State and the infinite variety of individual enterprise. To the older economists the difference seemed so great that they considered the presumption against State interference to be established. The rule, it is true, was never absolute and unqualified. Adam Smith himself indicated some of the most important of these exceptions, and the list has been extended by his successors. But these exceptions were all based upon reasoned principles, such

as the incapacity of the persons concerned, *e.g.*, children to make fair contracts, the lack of individual interest in public works, *e.g.*, the maintenance of roads, and the importance of the highest security, as in the regulation of the issues of bank-notes. And in spite of all these exceptions—strengthened and purified by these exceptions—the presumption remained undisturbed. Recently, however, some writers, under the influence of the ideal of maximum happiness and impressed by the power of the State, have sought to extend its interference far beyond these admitted principles. But I venture to say, so far as this movement had any theoretical support, the reaction has already begun.

The fundamental importance of freedom of contract has become more apparent than ever through the application of the comparative and historical methods to jurisprudence; the proposition that the progress of society has been from status to contract has almost acquired the force of an axiom. The analysis, too, of modern industrial systems, in which division of labour has become more and more intricate and interdependent, has shown the hopelessness of the attempt to transfer the management and control to the State. Changes in the methods of production, in the diffusion of knowledge, and in the transport of material commodities have been so rapid and so great that no executive government could have overtaken them. In the most advanced communities even that legislation which is necessary for the new conditions lags behind; even those elementary forms which simply aim at giving an interpretation to contracts in doubtful cases, or which are necessary for the adjustment of responsibility (as in bankruptcy and partnership), are behind the times. The growth of joint-stock enterprise has outstripped the development of the law of companies, and there is a crop of new frauds without corresponding penalties.

Turning to the executive and administrative functions of government, the analysis of existing conditions shows that we have not yet overtaken those exceptions admitted by the strongest supporters of *laisser-faire.* The British Government has, it is true, wasted its energies in devising temporary expedients of various kinds, but it has not yet accomplished the programme of Adam Smith. Not only are there privileges and restrictions that ought to have been abolished long ago, but on the positive side the programme is not complete. We have just begun universal education on the lines laid down by Adam Smith, but his scheme for Imperial federation is not yet within the range of practical politics. We have effected great financial reforms, but we still fall far short of the full development of his principles. Even in matters of currency and banking—in relation to which the function of the State has always been recognised—we are lamentably in need of reform.

But if the State cannot overtake those duties which are so necessary and persistent that they were forced on the attention of the strongest supporters of *laisser-faire,* how can we possibly justify the assumption of new functions which rest upon no better principle than the vague idea that the State ought to do something?

This leads me to observe that not only theoretically but practically signs of a reaction in favour of the old position are rapidly increasing. The experiments already made at playing the *rôle* of omnipotence and omniscience, against which Governments were so emphatically warned by Adam Smith, have begun to bring forth fruit after their kind; thorns that were carefully nursed by the legislature, instead of producing grapes, have produced more thorns and worse thorns.

A principle of the widest application in ethics and politics as well as in economics, which may be described as the principle of formal justice, has begun to operate in a remarkable manner. A Government which lends its power and assistance to one set of people must be prepared to act in a similar manner in all similar cases. If once this principle is abandoned, governmental action becomes either a matter of chance or depends upon clamour and jobbery. It is wonderful how quickly the human mind discovers analogies in grievances, and how soon one cry leads to another. Microbes are not more rapid and relentless in their multiplication. A plain man may have his doubts about the similarity of triangles and consent to arbitration on the question, but he has no doubt

that for the purpose of governmental grants and aids his needs are similar to his neighbour's. And the plain man is right. How can we justify the use of State credit for the purchase of lands in Ireland and fishing boats in Scotland if we are not prepared to give similar aid to the poor of England who are similarly situated? If we grant judicial rents in the country why not in the towns, and if we fix by law one set of prices why not all prices?

We must not be content with looking at the immediate effects of legislation; we must consider also the secondary and more remote consequences. If a legislator thinks that there are none of importance, let him read a chapter of Adam Smith—in the original and not in the stale pemmican of popular dogmatism. And if he still thinks that every law must be considered in isolation on its own merits, that it is a temporary remedy for a passing emergency, then let him resign his seat in Parliament; he has mistaken his vocation; in the name of common sense and the happiness of the greatest number let him cease to be a legislator and become a policeman.

There is an old fable about the gradual entrance, little by little, of the camel into the tent of the Arab. The British Government—I speak irrespectively of parties, for with the frankness of my old masters in political economy I make bold to say both are equally to blame—the British Government is beginning to find that the camel is getting too far into the tent. The admission of a single ear is nothing to the admission of the hump, and the knees, and the rest of the beast. Now the ear may be interpreted to mean the grant of a few thousand pounds to Scottish fishers, the hump is universal old-age pensions at a cost of some fifteen or twenty millions a year, and for the knees you may take the nationalisation of land at a cost of some two thousand millions, and for the whole beast you have the complete Socialist programme. The conclusion that when the beast was in the Arab was out needs no interpretation.

Let us leave fables for something the exact opposite, namely taxes. It was a favourite doctrine of the old economists that taxes are a burden and the visits of the tax-gatherer are odious. This doctrine also is beginning to reassert itself. The State can do nothing without money, and it generally does things in the most expensive manner. Fortunately in this country we have not yet reached the limits of tolerable taxation, but at the present rate of growth of Imperial and local expenditure we are rapidly approaching those limits. Now, if there is one position that has been firmly established in theory and confirmed by the abundant experience of many nations, it is that excessive taxation is ruinous to a country. We have to consider not only the net proceeds but the indirect cost in all its forms, not only the mere cost of collection but the effects on industry and on the energies of the people.

It may, of course, be replied that those who demand a large increase of expenditure for public purposes do not propose to tax the poor, but only to take the superfluities of the rich—to take, as is sometimes said, twenty shillings in the pound from that part of every income which extends above 400*l.* a year. The certain effect of this kind of taxation would be that in a very short time nobody would have more than 400*l.* a year, and the sources of taxation would dry up just as people had become used to and dependent on governmental assistance.

The general argument may be summarised in the favourite phraseology of the day. The utility of every increment of governmental work rapidly diminishes, and the disutility of every increment of taxation rapidly increases. Both propositions, I may add, were abundantly proved before the language I have just employed was invented, and the old language, if less scientific, conveyed a more emphatic condemnation.

I will conclude by calling your attention to one more position of the classical economists, and one that is the foundation of their whole system so far as they deal with the principles of governmental action. They maintain that even if the State could do something for individuals as cheaply and effectively as they could do it for themselves, it is in general better to trust to individual effort. The decisive consideration is the effect on the character and energies of the people. Self-reliance, independence, liberty—these were the old watchwords—not State

reliance, dependence, and obedience. In the matter of pauperism, for example, they teach us to distinguish between the immediate effects of relief which may be beneficial, and the effects of reliance on that relief which may be disastrous. They are bold enough to maintain that the condition of life of the dependent pauper should not be made by aids and allowances better than that of the independent labourer. They insist on the great historical distinction between the sturdy rogues and vagabonds—who can work and will not—and the impotent poor, the poor in very deed, who cannot support themselves. They look upon the payment of poor rates as they look upon other forms of taxation, namely, as the lesser of two evils; they do not try to persuade themselves and other people that it is a duty which is essentially pleasant. And I confess that I never yet met a man who had the audacity to assert that he enjoyed paying poor rates. But I have known many men who have given of their substance to a far greater extent with a cheerful spirit. It is the compulsion that sticks in the throat, and there is no more instructive chapter in economic history than that which describes the slow, painful processes by which Englishmen gradually adopted compulsory assessment for the relief of the poor. I shall be told that these old economic doctrines are cold and hard and opposed to the principles of Christian charity. The retort is easy: If Christian charity realised a tithe of its ideal there would be no need for relief on the part of the State. If I, too, may quote Scripture for my purpose I would say: Go to the ant, thou sluggard! It does not take ten ants to relieve another ant, and in this land of ours there are more than ten professed Christians to every pauper.

It is time, however, to bring this discourse to an end and not to begin a sermon; which, moreover, according to my masters the old economists, is beyond our domain. Yet I shall be bold enough to end with these words of advice: To the student I would say: Political economy has a vast literature, and you will not find all the good concentrated in the last marginal increment; you must master the old before you can appreciate the new; a portion of truth just rediscovered for the hundredth time by some amateur is not of such value as a body of doctrines that have been developed for more than a century by economists of repute. And to the legislator I would say: Vaster than the literature of political economy is the economic experience of nations; the lessons to be learned from the multitudinous experiments of the past can never become antiquated, for they have revealed certain broad features of human character that you can no more disregard than the vital functions of the human body. Just as Harvey did not invent but discovered the circulation of the blood, so Adam Smith did not invent but discovered the system of natural liberty. And nothing has been better established than the position that legislation which neglects to take account of the liberties of individuals is foredoomed to failure. If they cannot break through the law they will get behind the law. The first duty of the legislator is to take account of the natural forces with which he must contend, and the classical economists have made a survey and estimate of these forces which, based as it is on the facts of human nature and the experience of nations, it would be wilful folly to overlook.

The following Reports and Papers were read:—

1. *Report on the Teaching of Science in Elementary Schools.* See Reports, p. 566.

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2. *Report on the Methods of Economic Training adopted in this and other Countries.*—See Reports, p. 571.

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3. *The Improvement of Labourers' Cottages.* *By* Rev. J. O. Bevan, *M.A.*, *F.G.S.*

The author discussed the following questions:—
Influence of surroundings on health and character.
Taking stock of present condition of things.
Growing importance attached to health questions.
Additional knowledge of hygienic requirements.
Vastness of area involved.
Magnitude of numbers affected.
Considerations involved in constructing dwelling:

Affecting health.	Affecting efficiency.
Affecting comfort.	

Classes appealed to:

Landlords, farmers, labourers.	Hygienists, reformers.

Act of Parliament:
Additional powers conferred.

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4. *Index Numbers.* *By* Stephen Bourne.

FRIDAY, SEPTEMBER 15.

The following Papers were read:—

1. *On Agricultural Depression.* *By* H. H. Scott.

The business of farming is so popular that in all ages up to recent times men were inclined to drift into it, but the uninitiated find out to their cost that it is not without its full share of troubles and disappointments.

The decline in prices and the market value of agricultural products are now less than the cost of production, turning farming, which was never very money-making, into a money-losing process.

The causes of the decline:

The danger that farmers still having some money may come to realise that capital invested in the pursuit is no longer either profit-giving or safe, and may consequently withdraw both the money and themselves from the industry.

The alleviations suggested by theorists, and why they fail:

Alleviations which would tend to stay the rapid decline in agriculture, but although favourable in this direction might be construed by some people as unfavourable to those having no connection with land.

Alleviations which are practicable without doubt, because, although advantageous to agriculture, could not be construed as being correspondingly disadvantageous to the non-agricultural classes of this country.

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2. *The Diminution of the Net Immigration from the rest of the country into the great towns of England and Wales,* 1871–91. *By* Edwin Cannan, *M.A.*

In London, with the remainder of Middlesex and Surrey and the registration districts of Bromley, Dartford, Gravesend, Romford, and West Ham, the difference between the actual increase of population and the excess of births over deaths was 271,648 in the decade 1851 to 1860, 271,155 from 1861 to 1870, 304,918 from 1871 to 1880, and only 171,442 from 1881 to 1890. For fifteen other great urban districts, with a total population of six millions in 1891, the corresponding figures were 253,492, 215,342, 170,726, and 4,261.

Difference between the Increase of Population and the Excess of Births over Deaths.

Districts	1851–60	1861–70	1871–80	1881–90	Pop. 1891
London	+271,648	+271,155	+304,918	+171,442	5,935,812
Liverpool	+ 68,703	+ 56,907	+ 49,017	− 15,057	899,985
Manchester	+ 32,073	+ 31,754	+ 49,913	+ 17,700	892,494
Oldham	+ 11,444	+ 2,027	+ 22,903	+ 12,297	201,153
Birmingham . . .	+ 40,242	+ 22,220	+ 21,147	− 7,935	631,830
Wolverhampton . .	+ 16,030	− 43,493	− 45,692	− 44,434	540,265
The Potteries . .	+ 7,890	+ 8,299	− 12,261	− 9,454	242,646
Leeds	+ 11,090	+ 20,734	+ 6,763	+ 15,489	387,044
Bradford	− 11,723	+ 32,774	+ 13,712	− 2,069	341,881
Sheffield	+ 26,101	+ 26,647	− 1,868	+ 2,170	342,582
Nottingham . . .	+ 10,962	+ 1,947	+ 33,845	+ 2,445	331,458
Newcastle and Gateshead	+ 17,291	+ 15,439	+ 6,612	+ 27,572	328,066
Sunderland . . .	+ 6,787	+ 4,816	+ 5,115	− 5,443	158,793
Hull	+ 3,058	+ 13,310	+ 16,839	+ 7,156	213,689
Bristol	+ 1,232	+ 17,505	+ 7,034	− 6,912	326,217
Portsea Island . .	+ 12,312	+ 4,458	− 2,353	+ 10,736	159,278
Total . .	+525,140	+486,497	+475,644	+175,703	11,933,193

The net immigration into the towns is affected by migration between the towns and other countries as well as by migration between the towns and the rest of England and Wales. The immigration from Ireland, Scotland, the colonies and foreign countries must have been somewhat less from 1881 to 1890 than from 1871 to 1880, as the number of non-natives residing in England and Wales increased from 1,020,101 to 1,118,617 in the first period, and only from 1,118,617 to 1,119,896 in the second. This decrease of immigration into the country at large cannot possibly account for the whole of the diminution of net immigration into the towns. That the remainder can be accounted for by an increase of emigration from the towns to the colonies and foreign countries is shown to be highly improbable by the fact that the difference between the population of the predominantly urban counties and the number of persons in England and Wales who were born in those counties has not increased between 1881 and 1891, though it increased considerably between 1871 and 1881. The difference between the population of London with the rest of Middlesex and Surrey, and the natives of that area living in England and Wales, was 933,374 in 1871, 1,061,194 in 1881, and 1,056,401 in 1891. Between the population of Lancashire, Cheshire, Yorkshire, and Durham, and the natives of those counties, the difference was 826,384 in 1871, 1,032,995 in 1881, and 1,031,982 in 1891. In the case of Staffordshire the population outnumbered the natives by 38,233 in 1871 and by 3,660 in 1881, while in 1891 the natives outnumbered the population by 32,100. It seems certain, therefore, that there has been a diminution of net immigration from the rest of the country into the great towns.

Whether this means a diminution of 'the exodus from the country to the town' depends chiefly on the meaning given to that somewhat indefinite phrase.

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3. *On Poor Law and Old Age.* *By* Rev. J. Frome Wilkinson.

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4. *On Statistical Correlation between Social Phenomena.* *By* Professor F. Y. Edgeworth.

Correlation in statistics denotes such a connection between two (or *mutatis mutandis* more) measurable attributes (*e.g.*, height of stature and length of arm)

that to the mean value of one attribute corresponds, as being most probably (frequently) associated therewith, the mean value of the other attribute; and to every deviation from the mean of one attribute corresponds a deviation of the other attribute, equal to the former deviation multiplied by a certain factor which is constant for all values of the attributes.[1]

The theory, verified in the case of the animal organism, presumably extends to social phenomena. For in the latter as well as in the former case there presumably exists the condition from which the properties of correlation flow, viz., the agency of a number of independent causes. The theory of correlation is required to justify the method of ascertaining *typical* family budgets. The theory may be extended to cases where the attributes are not numerically measurable, such as 'dulness.'[2]

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5. *On the Lessons of the Australian Banking Collapse. By* C. GAIRDNER.

Conditions of deposit-banking in the colonies essentially different from those at home. Proportion borne by indebtedness to capital greater in the colonies than at home. Depositors at home not in touch with the management in the colonies. No means of sustaining confidence when once disturbed. Stipulation for notice prior to withdrawal of deposits of little avail in a time of discredit. Need for convertible reserves, and for a market where they can be converted. High rates of interest on deposits incompatible with maintenance of large reserves. Suggestion that deposits should be invited for longer periods, or in form of debenture stock criticised. Statistics relating to suspended banks. Liquidation being impracticable. Reconstruction inevitable. Necessity for rigid economy in management of reconstructed companies. Reduction of their number. Suppression of branches. Difficulties of the banks greatly aggravated by excessive borrowing through other channels. General inflation and subsequent collapse. Need for suppressing all extravagance and waste. Work and thrift sole means of surmounting financial difficulties. With favourable seasons recuperation may be rapid.

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6. *On Bishop Hugh Latimer as an Economist.*
By the Rev. W. CUNNINGHAM, *D.D.*

The 'Examination of Common Complaints,' which was issued by 'W. S.' in 1581, is the most remarkable English Economic tract of the sixteenth century, as is shown by the frequency with which it has been reprinted. Fresh interest has been given to it, however, since the discovery by the late Miss Lamond of two MSS. of this dialogue. She has proved that the text given by 'W. S.' is corrupt, and that the dialogue was written as early as 1549. She has also furnished good grounds for believing that Hugh Latimer is the original of the Doctor who takes such a leading part in the discussion. Her edition, which has just been issued by the Cambridge University Press under its proper title as a *Discourse of the Common Weal of this Realm of England,* not only fixes the date, but gives us a text which has not been tampered with, and which affords a sound basis for critical investigations as to the authorship and place of writing, as well as to the originals of the persons represented in the dialogue. The argument by which Latimer is identified is too detailed to summarise; but the case is a strong one, and if this view comes to be accepted, it will give a fresh interest to the economic principles which the Doctor advocates. These principles are remarkable in many ways. The *general position* which is taken is completely modern. The system of finance which is assumed is of a modern type, since taxation forms the ordinary source of revenue. But a more remarkable departure from the mediæval standpoint appears in the treatment of Self-interest. The Doctor does not merely denounce 'private lucre' as immoral, he recognises that it is a powerful agent which the statesman may control, so that it shall not be injurious at all, but shall tend to the advantage of the individual

[1] See F. Galton, *Proc. Roy. Soc.*, 1888.

[2] See Dr. Francis Warner, *Journal of the Statistical Society*, March 1893.

and of the community also. In matters of *economic doctrine* the Doctor advocates views both in regard to the effect of the debased currency on prices and to the importance of the balance of trade which were not current in his time, though they subsequently won general acceptance. He also anticipates the policy of a later time by his *practical suggestions* for agriculture and industry, as well as by his recommendations for the amendment of the coinage. The Doctor, in the original form of the dialogue, did not, however, recognise the effect on prices of the influx of American silver. The remarkable passage in the printed copies which calls attention to this phenomenon was interpolated by 'W. S.,' and does not appear in the MSS. Miss Lamond's edition adds immensely to the value of the dialogue as historical evidence, while it brings to light elements of personal interest which had hitherto been obscured. By her work on this *Discourse*, even more than by her edition of 'Walter of Henley,' Miss Lamond has succeeded, despite the difficulties with which she had to contend, in making additions of permanent value to our knowledge of English Economic History.

SATURDAY, SEPTEMBER 16.

The Section did not meet.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On Nottingham Lace and Fashion. By* J. B. Firth.

Nottingham no longer holds a complete monopoly of the lace trade, as she did thirty years ago, but she still has a monopoly in the manufacture of fine cotton lace, and it is upon the accident of this being in fashion that her prosperity depends. The ordinary constant yearly trade in lace is not sufficient to keep one-half of her lace machines employed; and as, roughly speaking, lace only becomes the predominant fashion once in ten years, it follows that for the trade to be depressed is the rule, for it to be prosperous the exception. The history of the trade shows that the fashion has usually lasted three seasons—one in which it is coming to its height, another in which it is paramount, and a third in which it gradually dies away. During these three years the manufacture of lace has been enormously profitable, and fortunes have been piled up with almost a dangerous ease; and they have dwindled away with the same ease during the periods of seven years' depression which have always followed the shorter bursts of prosperity. What is true of the profits of the master is also true of the wages of the workman; and the consequence has been that Nottingham has been forced to introduce other and more constant industries into the town to provide work for the men who are inevitably thrown out of employment by the bad times of the lace trade. The conditions of the industry are thus radically unsound, although they cannot be altered because the control of the fashion-books does not lie in the lace manufacturer's hands. He has to keep up his manufactory as if the normal condition of the trade were prosperity and not depression, for he never can be certain when the change will come, and he has to devote himself to precipitating the change by the beauty of his designs. Lace being a luxury, the taste of the public being capricious, the lace-making machines being excessively costly, and the processes of its manufacture necessitating its passage through so many hands, the result is that the flush of good trade is only obtained after years of patient loss, in which the manufacturers' energies are devoted to keeping down their losses rather than making profits; and the influence on the town has been both good and bad: good because the artistic properties of lace have insensibly improved the taste of all connected with its manufacture; bad because the character of the industry, dependent for

prosperity upon caprice, is directly opposed to thrift. Nor does it seem likely that the future of the Nottingham lace trade will be more stable than it has been in the past. Fashion is beginning to change more rapidly than it did, but, on the other hand, more things become fashionable in a single season, and the choice for the public is greater. There may be a greater volume of trade done as lace becomes increasingly popular with the million, but there are more rivals springing up to share that trade. Prices will never reach the fabulous height that the Nottingham monopolists used to obtain; and thus, while there is no diminution in the expensiveness of the manufacture, the profits will be seriously lessened.

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2. *On Agricultural Depression. By* W. J. ALLSEBROOK.

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3. *On Home Work—The Share of the Woman in Family Maintenance. By* Miss ADA HEATHER-BIGG.

A little while ago it was generally believed that excessive toil, starvation wages, and insanitary surroundings were due to the action of sub-contract. The painstaking inquiries of Mr. C. Booth, Mr. David Schloss, and Mrs. S. Webb soon showed that sub-contract was not responsible for these evils. It is now asserted that home work is. The outcry against sub-contract had been swelled by the antagonism of labour to capital—by the dislike of the man who works for wages to the man who works for profit.

The outcry against home work is being swelled by the hostility of the working man to the woman wage-earner.

Common sense and a fear of alienating public sympathy prevent the working-class leaders from too openly condemning the employment of women altogether, but special classes of women-workers are being constantly singled out for attack.

The wage-earning of married women (albeit in their own homes) is particularly denounced. It is alleged that this makes women joint earners with their husbands, and tends to substitute the wife for the husband as bread-winner.

As a matter of fact, however, women of the working classes always have been joint bread-winners with their husbands. At no time in the world's history has the man's labour alone sufficed for the maintenance of his wife and children. So far from keeping his wife, the true account of the matter is that he and she have kept themselves and the children.

This truth has long been admitted and acted upon in France. It was affirmed of England before the Ind. Remun. Conference. 'Not more than half the whole number of working-class families,' said Miss Simcox, are maintained by the labour of the father assisted only by the elder children.'

It has been shown to apply even to the United States, where, though the total family income is higher than in Europe, and the husband's contribution to it is also larger, there are only a few industries in which, unaided, he can support his family. Even in the bar-iron industry one-tenth has to be made up.

In Belgium it is calculated that the husband earns three-fifths and the wife two-fifths.

Talk about the gradual substitution of the woman for the man as bread-earner is absurd. The woman's share in household maintenance is no more than it ever was. The facts have not altered, but the conditions of modern industry enable us to see what the facts are.

In short, a *revelation* is going on, not a *substitution.*

Formerly, a woman working for a family in her home had to pick up faggots, fetch water, bake bread, spin flax and wool, cure, pickle, preserve, churn, wash, knit, &c.

To-day, at any rate in big cities, the wife's household work means only mending, washing, cleaning, cooking, care of children being the same in both cases.

Even amongst working men there are some enlightened enough to see that the ideal to be aimed at is not that the man should be the sole bread-winner, but

that bread-winning should go on under circumstances which secure the most comfortable life for the men, women, and children of the family, which permit the fullest development of all powers, and openly substitute economic co-operation on the part of the wife for economic dependence.

Such people ground their objections to home work on—

(1) Danger to public health.

(2) The low rate of pay in industries where home work prevails.

As to (1), if existing sanitary laws, properly enforced, do not safeguard the public, then no prohibition of home work would either.

As to (2), the smaller sum earned by a woman in her home may place her in as good a pecuniary position as the larger sum earned in a factory.

The advantages of home work outweigh all the drawbacks, because it enables married women to contribute their quota to household maintenance in the way most congenial to them, and most consistent with home life.

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4. *On the Progress of the Newspaper Press, and the Need of Reform and Consolidation of the Laws affecting it. By* Professor J. A. Strahan, *M.A., LL.B.*

Statistics showing the progress of the newspaper press.—In 1695 the first daily started in England. In 1712—when the stamp tax on newspapers was first imposed—the yearly circulation of newspapers in England was about 2,000,000. In 1755 it was about 7,400,000; in 1801, about 16,000,000; in 1836, about 39,400,000; in 1837—when the stamp tax was reduced from $3\frac{1}{4}d.$ net to $1d.$—about 54,000,000; in 1854—the last year of the stamp tax—about 122,000,000. Since 1854 estimates of circulation must be conjectural, but the great increase in the number of newspapers—from 493 in 1840 to 2,200 in 1893, of persons connected with journalism, *e.g.*, of 'reporters,' from 636 in 1861 to 2,677 in 1881—shows that newspaper production must have increased enormously. The yearly circulation of the twenty-nine London daily papers must approach 1,000,000,000, of the 170 provincial dailies must pass that number. Besides these there are now 2,000 weeklies in the United Kingdom, some of which have a weekly circulation approaching a million.

Legislation affecting newspapers.—For the first 150 years after the first daily was started there was practically no legislation specially affecting newspapers; during the last fifty years there has been plenty, but most of it has been haphasard and ill-considered.

Advantages which would result from codifying law.—(*a*) The law would be made more intelligible. This is very necessary, as the law has frequently to be applied by the editor without the opportunity of legal advice. (*b*) It would be made less cumbersome. (*c*) It would be made more effective. At present it frequently fails to carry out the intentions of the legislature. (*d*) It would be made more just. At present the journalist has too good grounds of complaint: (1) his liability to vexatious actions for merely technical libels; (2) his sole liability for defamation appearing in reports of speeches publicly delivered. Suggestions for dealing with these.

Suggestions for establishing a legally qualified profession of journalism.—One probable result of recasting law of the press—an enactment that henceforth no newspaper should be started without a legally qualified editor to conduct it, such editor to be liable to expulsion from the profession if shown to be guilty of unprofessional conduct.

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5. *On the Census of Foreigners in France. By* M. A. de Liégeard.

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6. *On Social and Economical Heredity. By* W. B. Grant.

The evil consequences of folly and wickedness are not exhausted in the sufferings of the individual, but are transmitted to offspring, and the misery and wretched-

ness found in town slums and elsewhere are largely due to inherited taint; so that individuals cannot properly be dealt with as if each was solely responsible. It is quite impossible amongst the living at some particular time to say on whom the responsibility should fall. Some national effort is therefore required, and must be directed to the removal of those who have proved themselves incapable of dealing with the difficulties of life, viz., *the criminal* and *the helpless.*

The remedy proposed is to found national compulsory colonies of two kinds, which might be called relief colonies for the helpless and retreat colonies for criminals. All the great national colonies have risen on the wealth derived from the soil; and under good superintendence it might be assumed that agricultural village colonies established and conducted under strict rule would be successful. For the relief colonies such discipline would be sufficient as has been ascertained to produce good results in the parish poorhouses of Scotland. The criminal colonies would require a firmer control, but both might easily be made more than self-supporting from the intelligent prosecution of cultivation, planting, pasture, and tillage appropriate to the particular localities selected.

Colonies might consist of family colonies of 100 persons, each on two square miles of land; and fifty family colonies would form a grand colony of convenient size, being ten miles square.

The criminals to be compulsorily emigrated would be least and at first those sentenced to penal servitude, and they would be astricted to their colonies for life. Individuals with a criminal taint would in this way have a better chance of leading useful lives than they could have in open competition; and the hereditary taint would gradually be eliminated from society.

The relief colonies would be for the submerged—those worsted in the battle of life, families and individuals found living without sufficient food, clothing, and lodging to assure permanent good health. These would not be astricted to their colonies for life, but would have an opportunity of working themselves free by their own self-denial and exertions.

The system would be established gradually. A single colony of each kind in different and suitable localities would first be settled, and others added as previous ones became self-supporting, the responsibility and expense to be undertaken by some existing Government department; and after the system had proved successful a separate Government department could be established.

By these or like means it is thought that the population of our islands could be gradually purified, strengthened, and elevated; and a new era of prosperity would thus become possible for the United Kingdom.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *On the Currency Problem. By* Prof. H. S. Foxwell, *M.A.*

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2. *On the Currency Question practically considered from a Commercial and Financial Point of View. By* W. E. Dorrington.

Currency is an international question. It is the keystone of the commercial arch, and, unless we revert to barter, a well-regulated system of currency is the only means whereby wholesale production can be adjusted to retail consumption.

Gold monometallism is a barrier to the development of free trade. The present position of the Customs tariffs in foreign countries, necessitated by the various nations endeavouring to keep their gold, and also induced by the efforts of foreign Governments to help their manufacturers against constantly falling prices, has fostered protection.

As the standard of value in a portion of the world is in silver, and in the other part in gold, commerce requires a stable par of exchange between gold and silver moneys; and, as the exigencies of business necessitate contracts for prolonged periods, the industrial and commercial world requires a stable standard of value for the equitable settlement of such contracts.

It is also most important to industrial and commercial Britain that foreign debtor nations shall not suffer by having to send to their foreign bondholders—English or otherwise—on account of an alteration in the standard, an unfair and unexpected increased amount of produce in discharge of external debts, to the impoverishment of such debtor countries, and their consequent and corresponding inability to purchase our goods.

Gold alone does not furnish a stable measure of value; silver is much more stable. Having regard to the existing standards and currencies of the world, a joint standard of the two metals, as of old, but on a broader international basis, would afford the best promise of stability. It is a fallacy to suppose that if prices of commodities fall producers or manufacturers get an immediate *pro ratâ* reduction of their costs of production. Many adjustments are only slowly effected; some elements of cost cannot be adjusted.

The industrial capitalist therefore suffers, and labour must sooner or later share the loss.

A silver-standard country with products or manufactures competing with those of gold-standard Britain has an unfair advantage over the producers or manufacturers of this country.

The increasing scramble for gold throughout the world must, unless relieved by a broadening of the monetary metallic base, increase and intensify and prolong financial tension and panic. Great Britain, being practically the only country whose monetary laws afford no means of protecting its gold, except the clumsy and ofttimes slowly efficacious procedure of raising the Bank rate, must experience to the fullest extent the evils of such financial disturbance. This affects credit, checks trading facilities and trade and enterprise, and puts a tax upon productive industry.

The only remedy which it is even suggested would give a stable par of exchange between the various peoples on earth; which would give a steady and permanent measure of value between buyers and sellers who make prolonged contracts, and between debtors and creditors, individual and national; and the only remedy to relieve the 'scramble for gold' and provide a suitable expansion of 'international legal tender' from time to time is international bimetallism. Monetary history proves that this would provide all these desiderata, and also proves that it is practicable.

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3. *On some Objections to Bimetallism viewed in connection with the Report of the Indian Currency Committee.* *By* L. L. PRICE.

The publication of the Report of the Indian Currency Committee marks a stage of great importance in the progress of the monetary crisis, and the report is not devoid of instruction for the student of monetary affairs. The aim of the present paper is to examine a few of the points on which such instruction may be obtained. Bimetallism is frequently charged with being artificial, and the objection is undeniably plausible. But the student will not dismiss the proposal on that ground alone, for he is aware of the abuse which often attaches to the distinction between what is natural and what is artificial. The layman, however, may be prejudicially influenced by the charge; but the review of foreign systems of currency contained in the Report of the Indian Currency Committee should suffice to convince him that, compared with these complicated systems, which are in many cases the consequence of the abandonment of bimetallism, or of the refusal to return to it, the bimetallic scheme appears simple and natural. Another consideration raised by the report is the fact that a currency change has now been sanctioned, which is distinctly designed to meet evils occasioned by currency changes. The particular phase of the malady with which the Indian Committee deal is that connected

with fluctuations of exchange, and they do not profess to effect a complete cure, but to check the further inroads of the disease. In England and Europe the more prominent phase is rather that of an 'appreciation' of gold. To deny the existence of this is now hardly possible, in whatever sense the term 'appreciation' is used, and to ignore the evils which are consequent upon it is no less difficult, while the Indian analogy renders inapplicable the plausible argument that Governments should not 'tamper' with the currency. And yet this argument, together with that based on the supposed artificial character of bimetallism, not improbably supplies a large part of the *vis inertiæ* which hinders its progress in this country, and does so in the minds of candid practical men honestly desirous to set aside prejudice. It is to them that the appeal must be made, and they may fairly be asked at the present juncture to give their careful attention to the question, for the action of the Indian Government is likely to accentuate the monetary difficulties of the Western world. Directly and indirectly it can hardly fail to increase the appreciation of gold. It may indeed so intensify the troubles as to compel attention to what was unheeded before, and thus out of present evil future good may possibly issue. But, with a view of shortening the period of suspense, the candid observer may be asked to contemplate the dilemmas to which the refusal of bimetallism has brought those who are anxious to relieve by other means the pressure of monetary difficulties. The Indian proposal illustrates some of these dilemmas, and is at the best acknowledged to be but a *pis aller*. It affords a fresh example of the dangers and difficulties of a policy of drift, and the practical man may now be asked whether he is really willing that such a policy should indefinitely continue. Happily there have of late been signs that the crust of indifference is being broken through, and to this beneficial process the Report of the Indian Currency Committee promises to render material assistance.

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4. *On India and the Currency.* *By* F. C. Harrison.

India's action was dictated by political and financial considerations—political in that the import trade and the official were suffering, financial in that Government found both the variation and the continuous decline in silver intolerable.

As India has always possessed a favourable balance of trade whether gold was dear as in 1835 or cheap as in 1866, whether silver was dear as in 1870 or cheap as in 1893, so it will continue to have a favourable balance under altered conditions. There is, therefore, no reason for supposing that the present experiment will fail owing to changes in international trade.

On other grounds India's action is also defensible. Europe is not at present prepared to adopt bimetallism, and many think that it is possible to manage with a gold standard and an extended use of silver and silver notes. India, therefore, by adopting the gold standard and using the least possible quantity of that metal in its circulation is doing the least injury that is practicable in changing from silver to gold.

SECTION G.—MECHANICAL SCIENCE.

PRESIDENT OF THE SECTION—JEREMIAH HEAD, Esq., M.Inst.C.E., F.C.S.

THURSDAY, SEPTEMBER 14.

The PRESIDENT delivered the following Address:—

THIS Section of the British Association for the Advancement of Science was founded with the object of making more widely known, and more generally appreciated, all well-ascertained facts and well-established principles having special reference to mechanical science.

As President of the Section for the year, it becomes my duty to inaugurate the proceedings by addressing you upon some portion of the scientific domain to which I have referred, and in which your presence here indicates that you are all more or less interested.

MECHANICAL SCIENCE.

The founders of the British Association no doubt regarded the field of operations which they awarded to Section G as a not less purely scientific one than those which they allotted to the other Sections. And, indeed, mechanical science studied, say, by Watt was as free from suspicion of commercial bias as chemical science studied, say, by Faraday.

But whatever may have been the original idea, the practice of the Section has recently been to expend most of its available time in the consideration of more or less beneficial applications of mechanical science, rather than of the first principles thereof. Our Section has become more and more one of applied rather than of pure science. None of the other Sections is free from this fault, if fault it be (which I do not contend or admit), but Section G seems to me to be beyond all question, and beyond all others, the Section of applied science.

The charter of the Institution of Civil Engineers commences by reciting that the object of that society is 'the general advancement of mechanical science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a civil engineer, being the art of directing the great sources of power in nature for the use and convenience of man.'

It seems that in 1828, when the Institution was incorporated, the term 'mechanical science' had a wider meaning than it is now usually understood to have. For, according to the charter, the art of directing the great sources of power in nature is only a particular species of knowledge which 'mechanical science' includes.

In 1836, or eight years later, the founders of our Section adopted the term without again defining it. Probably they accepted the careful definition of the Great George Street Institution. Time has shown the wisdom of that decision. For we civil engineers and other frequenters of Section G in active practice need far more knowledge than mechanical science can teach us in the ordinary or narrow sense of the term. Our art in its multifarious branches requires, if success is to be

attained, the acquisition and application of almost all the other sciences which belong to the fields of research relegated to the other Sections. For how could the gigantic engineering structures of modern times be designed without recourse to mathematics, or steam and other motors without a knowledge of physics, or modern metallurgical operations be conducted without chemistry, or mining without geology, or communications by rail, ship, and wire be established and carried on with all parts of the world without attention to geography, or extensive manufacturing enterprises be developed if the laws of economics were neglected?

As to biological studies, they seem at first sight to have but little to do with mechanical science. It might even be thought that the civil engineer could afford altogether to neglect this part of the work of the Association. But I trust I shall be able to show you before I finish that any such view is absolutely untenable.

MECHANISMS IN NATURE.

Indeed, I hope, in the course of this address, to satisfy you that mechanical science is largely indebted to mechanisms as they exist in nature, if not for its origin, at all events for much of its progress hitherto, and that nature must still be our guide.

Mechanical science has been built up entirely upon observation and experiment, and the natural laws which have been induced therefrom by man. The lower animals in their wild condition work with tools or appliances external to their bodies to but a very slight extent, and man in a primitive or savage state does the same. But many, if not most, animals can be taught to use mechanisms if carefully trained from infancy. Thus, the well-known donkey at Carisbrooke Castle draws water from a deep well by a treadmill arrangement just as well as a man could do it. He watches the rope on the barrel till the full pail rises above the parapet of the well, then slacks back a little to allow it to be rested thereon, and only then leaves the drum and retreats to his stable. But, according to his attendant, four years were needed for his education, and unless it had been commenced early it would have been useless.

I have seen a canary gradually lift from a little well, situated a foot below its perch, a thimble full of water by pulling up with its beak, bit by bit, a little chain attached to it, and securing each length lifted with its foot till it could take another pull. When the thimble reached its perch level the bird took a drink, and then let it fall back into the well. Numerous other examples will doubtless occur to you.

But though animals can be taught to make use of mechanical appliances provided for them—a fact which shows the existence in their brains of a faculty corresponding in kind, if not in degree, to the mechanical faculty in man—they rarely, on their own initiative, make use of anything external to their bodies as tools; and still more rarely, if ever, do they make, alter, or adapt such mechanical aids. Mr. C. Wood, of Middlesbrough, informs me that certain crows which frequent oyster-beds on the coast of India wait until the receding tide uncovers the oysters, which still remain open for a time. A crow will then put a pebble inside one, and, having thus gagged it and secured his own safety, will proceed to pick it out and eat it at leisure. A monkey will crack a nut between two stones, and will hurl missiles at his enemies. But in some countries he is systematically entrapped by tying to a tree a hollow gourd containing rice, and having a hole large enough for his hand, but too small for his clenched fist, to pass through. He climbs the tree and grasps the rice, and remains there till taken, being too greedy, and not having sufficient sense, to let go the rice and withdraw his hand.

This is on a par with the snuff-taking imbecile, described by Hugh Miller,[1] whom the boys used to tease by giving him a little snuff at the bottom of a deep tin box. The imbecile would try to get at it for hours without the idea ever occurring to him that he might achieve his object by turning the box upside down.

All animals are, however, in their bodily frames, and in the intricate processes

[1] *My Schools and Schoolmasters*, by Hugh Miller.

and functions which go on continuously therein, mechanisms of so elaborate a kind that we can only look and wonder and strive to imitate them a little here and there. The mechanism of their own bodily frames is that with which the lower animals have to be content, and whilst they are in the prime of life and health, and in their natural environment, it is generally sufficient for all their purposes. Man has a still more perfect, or rather a still more versatile, bodily mechanism, and one which in a limited environment would be equally sufficient for his needs. But he has also an enterprising and powerful mind which impels him to strive after and enables him to enjoy fields of conquest unknown to, and uncared for by, the relatively brainless lower animals.

Urged on by these superior mental powers, man must soon have perceived that by the use of instruments he could more quickly and easily gain his ends, and he would not be long in discovering that certain other animals, such as the ox and the horse, were teachable and his willing slaves, provided only he fed and trained them and treated them kindly.

First, in common with other animals, he would find out that stones and sticks were of some use as weapons and tools; then he would go further and utilise skins and thongs for clothing and harness; and by selecting and modifying his stones and sticks he would form them into rough implements, which would enable him to cut down trees and to make rude huts and boats. Animals caught and domesticated would first be taught to haul light logs along the ground, then to move heavier ones on rollers; and later, in order to avoid the necessity for continual replacement of the rollers, the wheel and axle would be gradually developed.

The mechanical nomenclature of all languages is largely derived from the bodies of men and other animals. From this it is clear that animals have always been recognised as mechanisms, or as closely related thereto. The names borrowed from them generally indicate a resemblance in form rather than in function, though not invariably so.

Thus in our own language we have the 'head' of a ship, a river, a lake, a jetty, a bolt, a nail, a screw, a rivet, a flight of stairs, and a column of water; the brow of an incline; the crown of an arch; the toe of a pier; the foot of a wall; the forefoot, heel, ribs, waist, knees, skin, nose, and dead eyes of a ship; also turtle backs and whale backs; the jaws of a vice; the claws of a clutch; the teeth of wheels; necks, shoulders, eyes, nozzles, legs, ears, mouths, lips, cheeks, elbows, feathers, tongues, throats, and arms; caps, bonnets, collars, sleeves, saddles, gussets, paddles, fins, wings, horns, crabs, donkeys, monkeys, and dogs; flywheels, running nooses, crane necks, grasshopper engines, &c.

Not only has our mechanical nomenclature been largely taken from animals, but many of our principal mechanical devices have pre-existed in them. Thus, examples of levers of all three orders are to be found in the bodies of animals. The human foot contains instances of the first and second, and the forearm of the third order of lever. The patella, or knee-cap, is practically a part of a pulley. There are several hinges and some ball-and-socket joints, with perfect lubricating arrangements. Lungs are bellows, and the vocal organs comprise every requisite of a perfect musical instrument. The heart is a combination of four force-pumps acting harmoniously together. The wrist, ankle, and spinal vertebræ form universal joints. The eyes may be regarded as double-lens cameras, with power to adjust focal length, and able, by their stereoscopic action, to gauge size, solidity, and distance. The nerves form a complete telegraph system with separate up and down lines and a central exchange. The circulation of the blood is a double-line system of canals, in which the canal liquid and canal boats move together, making the complete circuit twice a minute, distributing supplies to wherever required, and taking up return loads wherever ready without stopping. It is also a heat-distributing apparatus, carrying heat from wherever it is generated or in excess to wherever it is deficient, and establishing a general average, just as engineers endeavour, but with less success, to do in houses and public buildings. The respiratory system may be looked upon as that whereby the internal ventilation of the bodily structure is maintained. For by it oxygen is separated from the air and imparted to the blood for conveyance and use where needed, whilst at the same time the

products of combustion are extracted therefrom and discharged into the atmosphere.

Mastication, which is the first process in the alimentary system, is, or rather should be, a perfect system of cutting up and grinding, and to assist and save animal, and especially human, mastication is the chief aim and object of all the gigantic milling establishments of modern times. The later alimentary processes are rather chemical than mechanical, but still the successive muscular contractions, whereby the contents of the canal are forced through their intricate course, are distinctly mechanical, and may have suggested the action of various mechanisms which are used in the arts to operate on plastic materials, and cause them to flow into new forms and directions.

The superiority of man to the lower animals can only have become conspicuous and decided when he began to use his inventive faculties and to fashion weapons and implements of a more efficient kind than the sticks and stones which they also occasionally use.

But human races and individuals were never equally endowed by nature. Some individuals would have greater inventive powers than others, and these and their posterity would gradually become dominant races. Large masses of mankind are still more or less in the position of primeval man, which, if we accept the conclusions of Darwin, Lubbock, and other modern scientists, we must regard as one of barbarism. For they are still without tools, appliances, and clothes, except of the most elementary kinds, and mechanical science might almost be non-existent, so far as they are concerned.[1]

It would obviously be impossible for me to treat of or call attention even to an infinitesimal extent to the results of mechanical science which surround us now so profusely, and which make our life so different from that of primeval man; and, even if it were possible, it would be quite unnecessary. We have all grown up in a mechanical age. We are so familiarised with artificial aids that we have come to regard them as part of our natural environment, and their occasional absence impresses us far more than their habitual presence.

I propose, with your leave, to proceed to the consideration of how far man is, in his natural condition, and has become by aid of mechanical science, able to compete successfully with other and specially endowed animals, each in its own sphere of action.

BODILY POWERS OF MAN AND OTHER ANIMALS.

The bodily frame of man is adapted for life and movement only on or near to the surface of the earth. Without mechanical aids he can walk for several hours, at a speed which is ordinarily from 3 to 4 miles per hour. Under exceptional circumstances he has accomplished over 8 miles[2] in one hour, and an average of $2\frac{3}{4}$ miles per hour for 141 hours.[3] In running he has covered about $11\frac{1}{2}$ miles in an hour. In water he has proved himself capable of swimming 100 yards at the rate of 3 miles per hour, and 22 miles at rather over 1 mile per hour. He can easily climb the most rugged mountain path and descend the same. He can swarm up a bare pole or a rope, and when of suitable physique and trained from infancy can perform those wonderful feats of strength and agility which we are accustomed to expect from acrobats. He has shown himself able to jump as high as 6 feet $2\frac{3}{4}$ inches from the ground, and over a horizontal distance of 23 feet 3 inches, and has thrown a cricket-ball as far as $382\frac{1}{2}$ feet before it struck the ground.[4]

The attitude and action of a man in throwing a stone or a cricket-ball, where he exerts a considerable force at several feet from the ground, to which the reaction has to be transmitted and to which he is in no way fastened, are unequalled in any artificial machine. The similar but contrary action of pulling a rope horizontally, as in 'tug of war' competitions, is equally remarkable.

[1] Mr. H. L. Lapage, M.Inst.C.E., who has just returned from Western Australia, states that he found the natives of both sexes and all ages absolutely nude.

[2] *Whitaker's Almanack*, 1893, p. 395.

[3] Recent pedestrian race from Berlin to Vienna.

[4] *Chambers's Encyclopædia*, 'Athletic Sports.'

So also the power of the living human mechanism to withstand widely diverse and excessive strains is altogether unapproachable in artificial constructions. Thus, although fitted for an external atmospheric pressure of about 15 lb. per square inch, he has been able, as exemplified by Messrs. Glaisher and Coxwell in 1862, to ascend to a height of 7 miles, and breathe air at a pressure of only 3½ lb. per square inch, and still live. And, on the other hand, divers have been down into water 80 feet deep, entailing an extra pressure of about 36 lb. per square inch, and have returned safely. One has even been to a depth of 150 feet, but the resulting pressure of 67 lb. per square inch cost him his life.[1]

Recent fasting performances (if the published records are to be trusted) are not less remarkable when we are comparing the human body as a piece of mechanism with those of artificial construction. For what artificial motor could continue its functions forty days and nights without fuel, or, if the material of which it was constructed were gradually consumed to maintain the flow of energy, could afterwards build itself up again to its original substance?

These and other performances are, when considered individually and separately, often largely exceeded by other animals specially adapted to their own limited spheres of activity. The marvel is not, therefore, that the human bodily mechanism is capable of any one kind of action, but that, in its various developments, it can do all or any of them, and also carry a mind endowed with far wider powers than any other animal.

Animals other than man are also adapted for life and movement on or about the surface of the earth. This includes a certain distance below the ground, as in the case of earthworms; under the water, as in the case of fish; on the water, as in the case of swimming birds; and in the air, as with flying birds.

As far as I know, no animal burrows downwards into the earth to a greater depth than 8 feet,[2] and then only in dry ground. Man is naturally very ill-adapted for boring into the earth as the earthworm does. Indeed, without mechanical aids he would be helpless in excavating or in dealing with the accumulations of water which are commonly met with underground. But by aid of the steam-engine for pumping, for air-compressing, ventilating, hauling, rock-boring, electric lighting, and so forth, and by the utilisation of explosives, he has obtained a complete mastery over the crust of the earth and its mineral contents, down to the depth where, owing to the increase of temperature, the conditions of existence become difficult to maintain.

I have said that on land man, unaided by mechanism, has been able to cover about 11½ miles in one hour. Two miles he has been able to run at the rate of nearly 13 miles per hour, and 100 yards at the rate of over 20 miles per hour.[3] But the horse, though he cannot walk faster than man, nor exceed him in jumping heights or distances, can certainly beat him altogether when galloping or trotting. A mile has been galloped in 103 seconds, equal to 35 miles per hour, and has been trotted in 124 seconds, equal to 29 miles per hour.[4]

There are many other animals, such as ostriches, greyhounds, antelopes, and wolves, which run at great speeds, but reliable records are difficult to obtain, and are scarcely necessary for our present purpose.

MECHANICAL AID WITHOUT EXTRANEOUS MOTIVE-POWER.

Let us now consider how man's position as a competitor with other animals in speed is affected by his use of mechanical aids, but without any extraneous motive-power.

Locomotion on Land.—Where there is a stretch of good ice, and he is able to bind skates on his feet, he can thereby largely augment his running speed. This was exemplified by the winner of the match for amateurs at Haarlem last winter, who accomplished the distance of 3·1 miles at the rate of about 21 miles per hour.

[1] *Pall Mall Gazette*, July 5, 1893, p. 8.
[2] *Vegetable Mould and Earthworms*, by Charles Darwin, p. 111.
[3] *Chambers's Encyclopædia*, 'Athletic Sports.'
[4] *Ibid.*, 'Horse.'

But the most wonderful increase to the locomotive power of man on land is obtained by the use of the modern cycle. Cycling is easily performed only where roads, wind, and weather are favourable. But similar conditions must also be present to secure the best speed of horses, with which we have been making comparison. One mile has been cycled at the rate of 27·1 miles per hour,[1] 50 at 20,[2] 100 at 16·6,[2] 388 at 12·5,[3] and 900 at 12·43[1] miles per hour.

The recent race between German and Austrian cavalry officers on the high road between Vienna and Berlin has afforded an excellent opportunity to judge of the speed and endurance of horses as compared with men over long distances. Count Starhemberg, the winner, performed the distance, about 388 miles, in 71·33 hours, equal to 5·45 miles per hour. He rested only one hour in twelve. His horse, though successful, has since died.[4]

Lawrence Fletcher cycled, also along the high roads, from Land's End to John o' Groat's house, 900 miles, in 72·4 hours, equal to 12·43 miles per hour, or more than double the distance that the Count rode, and at above double the speed. To the best of my knowledge he still lives, and is no worse for his effort. The horse in this case would have to carry extra weight equal to one-sixth of his own, and the cyclist equal to a quarter of his own. But the horse carried himself and his rider on his own legs, while the cyclist made his machine bear the weight of itself and rider. Herein was probably the secret of his easy victory.

With the very remarkable exception of long-distance cycling, which is of limited application, man, relying on his own bodily strength, cannot successfully compete with other animals which, like the horse, are specially fitted for rapid land locomotion. His only alternatives are either to utilise the horse and ride or drive him, and so get the benefit of his superior strength and speed, or to use his own inventive faculty and construct appliances altogether apart from animal mechanisms. In either case he virtually gives up the contest as a self-moving animal, and to a great extent abandons himself to be carried by others or by inanimate machinery.

Nearly seventy years ago mankind came to this conclusion, and the modern railway system is the result. The locomotive will go at least double the speed of the racehorse. It will carry not only itself but three or four times its own weight in addition, and will go not 2 or 3, but 100 miles or more without stopping, if only the road ahead be clear. And the iron horse is fed and controlled without even so much exertion as that put forth by a man on a horse of flesh and bone.

Locomotion in Water.—Let us now consider the powers of man relatively to other animals in moving upon and through the great waters with which three-fourths of the earth's surface is covered. Here he is in competition with fishes, aquatic mammals, and swimming birds.

I have already stated that, unaided by mechanism, he has shown himself able to swim for short distances at the rate of 3, and long distances (22 miles) at the rate of 1 mile per hour. He has also given instances of being able to remain under water for 4½ minutes.[5]

Credible eye-witnesses inform me that porpoises easily overtake and keep pace with a steamer going 12½ knots, or, say, over 14 miles per hour, for an indefinite length of time. This is five and fifteen times the maximum swimming speed of a man for short and long distances respectively. No doubt the form and surface of a fish whose main business is swimming offer less resistance, and his muscular power is more concentrated and better applied towards propulsion in water than is the case with man, whose body is also adapted for so many other purposes.

I am further informed by Mr. Nelson, of Redcar, a naturalist who has made the experiment, that it is impossible for an ordinary sea-boat, rowed by two men and going at 5 miles per hour, to overtake the aquatic bird called the Great Northern Diver when endeavouring to make his escape by alternately swimming

[1] *Whitaker's Almanack*, 1893.
[2] *Chambers's Encyclopædia*, 'Cycling.'
[3] *Times*, Sept. 26 to Oct. 7, 1892.
[4] Vienna-Berlin Race, June 1893.
[5] *Whitaker's Almanack*, 1893.

on the surface and diving below. His speed is therefore nearly double the short and five times the long distance speed of unaided man in water. As regards remaining under water, fishes properly so called have unlimited powers, and even aquatic mammals, such as whales, can remain under for $1\frac{1}{2}$ hour.

Using only his own strength, but assisting himself with mechanical devices, man has been able to increase considerably his speed as a swimming animal. Mr. John McCall, of Walthamstow, informs me that in 1868 he constructed and repeatedly used an apparatus which acted like the tail of a fish. It consisted of a piece of whalebone, having a broad yet thin and elastic blade, tapering into a shank like the end of an oar. The blade was 15 inches wide and 4 feet long, including the shank. To the end of the latter a horizontal cross-bar 13 inches long was fitted, and leather pockets were provided at the ends for the feet. By swimming on his back and striking out alternately with his legs, he was able, with the assistance of this apparatus, to keep up with a sea-boat pulled by two men at about 4 miles per hour.

By means of boats, which he propels by oars or sculls, and notwithstanding the increased weight, and therefore displacement, involved by them, man has been able to increase his speed on the surface of the water to a maximum of about 12 miles per hour for about 4 miles distance, under favourable circumstances. So, by supplementing his bodily powers by means of mechanical aids, such as the diving-bell and the diving-helmet, dress, and air-pump, or by the portable self-acting apparatus used with such good effect in the construction of the Severn Tunnel, man has been able to approach very nearly to the natural diving powers of, at all events, aquatic mammals, except that he cannot move about in subaqueous regions with anything approaching their ease and celerity.

Invariably on water, as almost invariably on land, man is quite unable to compete in power of locomotion with other specially adapted animals, whether or not he avails himself of mechanical aids, so long as his own bodily strength is the only motive-power he employs. He has gradually come to recognise this fact, and to see that he must use his inventive faculties and find new and powerful motors external to himself if he would really claim to dominate the great waters of the earth.

The fastest mechanism of any size, animal or man-made, which, as far as I know, has ever cut its way through the waters for any considerable distance is the torpedo-boat 'Ariete,' made by Messrs. Thornycroft & Son, of London, in 1887. It has a displacement or total weight of about 110 tons, and machinery capable of exerting 1,290 effective horse-power, or 11·7 horse-power per ton of weight or displacement; or, to put it in another form, an effective horse-power is by it obtained from a weight of 191 lb., which includes vessel, machinery, fuel, stores, and attendants. The speed accomplished at the trials of this little craft, being the average of six one-mile tests, was 26·18 knots, or 30·16 miles per hour.[1] As might be expected, it resembles a fish, in that its interior is almost exclusively devoted to the machinery and accessories necessary for propulsion. During the trials the water, fuel, stores, and other ponderable substances carried amounted to 17·35 tons. Two similar boats were able to make the voyage to South America by themselves, though at much slower speed and replenishing their fuel on the way. No fish or swimming bird can match this performance. And inasmuch as 191 lb. of dead weight produced 1 horse-power, as compared with from 150 to 250 lb. in certain flying birds, it would seem that with suitable adaptations the 'Ariete' might even have been made to navigate the air instead of the water.[2] But I will revert to this subject later on.

Where safety in any weather, and passenger- and cargo-carrying powers are aimed at, as well as, or prior to, the utmost attainable speed—and these must ever

[1] *Engineering*, July 15, 1887.

[2] M. Normand, of Havre, is building for the French Government two torpedo-boats, each having a displacement of 125 tons and 2,717 effective horse-power, or 21·7 horse-power per ton of displacement. This is equivalent to 1 horse-power per 103 lb., and is still within the limits of weight permissible for aërial flight (see *Times*, June 19, 1893).

be the leading features of ocean-transit steamers if they are to attain commercial success—there I must refer you to those magnificent examples of naval architecture which are more or less familiar to you all, and of which we, as a maritime nation, are so justly proud. If, for example, we turn our attention for a moment to the new Cunard liners, the 'Campania' and 'Lucania,' having each a weight or displacement of 18,000 tons and 24,000 effective horse-power, or 1·33 horse-power per ton of displacement, we shall find that, with the commercial advantages alluded to, they obtain a maximum speed of 22·5 knots, or about 26 miles per hour.

If, instead of 1·33 effective horse-power per ton of displacement, they were provided with eight times that amount, or 10·64 horse-power per ton, thereby sacrificing passenger and cargo accommodation, and making them nearly as full of propelling machinery as the 'Ariete' torpedo-boat, and if it were then found possible to apply this enormous power effectively, then there is every reason to believe they would accomplish for short distances double the speed, or, say, 45 knots, or about 52 statute miles, per hour.

By inventing and utilising mechanical contrivances entirely independent of his own bodily strength, man can now pass over the surface of the waters at the rate of over 500 knots per day, and at the same time retain the comforts and conveniences of life as though he were on shore. He has in this way beaten the natural and specially fitted denizens of the deep in their own element, as regards speed and continuity of effort. But he is still behind them as to safety. We do not find that fishes or aquatic mammals often perish in numbers, as man does, by collisions in fogs, or by being cast on lee shores and rocks by stress of weather. Shall we ever arrive at the point of making ocean travelling absolutely safe? The Cunard Company is able to boast that from its commencement, fifty-three years ago, it has never lost a passenger's life or a letter; a statement which gives ground for hope that almost absolute safety is attainable. But, on the other hand, other owners of almost equal repute (not excluding the British Admiralty) are ever and anon losing magnificent vessels on rocks, in collisions, by fire, and even by stress of weather, in a way which makes us doubt whether it is possible for Britannia or any one else really to 'rule the waves.'

In one way the chances of serious disaster have been of late largely diminished, and here, again, Nature has been our teacher. The bodies of all animals except the very lowest are symmetrically formed on either side of a central longitudinal plane. Each important limb is in duplicate, and if one side is wounded the other can still act. We have at last found out the enormous advantage and increased safety of having the whole of our ship-propelling machinery in duplicate, and our ships made almost unsinkable by one longitudinal and numerous transverse bulkheads.

Locomotion in Air.—I now come to consider what is the position of man as regards locomotion in and through the great atmospheric envelope which surrounds the earth, in comparison with animals specially fitted by Nature for such work.

Nature seems never to bestow all her gifts on one individual or class of animals, and she never leaves any entirely destitute. For instance, the serpent, having no limbs whatever, would seem at first sight to be terribly handicapped; yet, in the language of the late Professor Owen, 'it can outclimb the monkey, outswim the fish, outleap the jerboa, and, suddenly loosing the close coils of its crouching spiral, it can spring into the air and seize the bird on the wing.'[1] Here we have the spiral spring in nature before it was devised by man.

Flying animals seem to conform remarkably to this law. Thus we have birds, like the penguin, which dive and swim, but cannot fly; others, like the gannet, which dive, swim, fly, and walk; others, like the ostrich, which run, but can neither fly nor swim; and numberless kinds which can fly well, but have only slight pedestrian powers.

Man, unaided by mechanisms, can, as we have seen, walk, run, swim, dive, and jump, and perform many remarkable feats; but for flying in the air he is absolutely unfitted. All his attempts (and there have been many) have up to the present been unsuccessful, whether or not he has availed himself of mechanical aids to his

[1] Pettigrew on *Animal Locomotion.*

own bodily powers. It is said that a certain man fitted himself with apparatus in the time of James VI. of Scotland, and actually precipitated himself from the cliff below Stirling Castle, in sight of the king and his courtiers; but the apparatus collapsed, and he broke his leg, and that was the end of the experiment.

But why should not man fly? It is not that he does not desire to do so. For every denizen of our precarious British climate, when he has noticed the ease with which swallows and other migratory birds fly off on the approach of winter, hundreds and even thousands of miles to the sunny south, must have wished he could do the same. One reason why we cannot fly, even with artificial aids, such as wings, is that, as in the case of the penguin or the ostrich, our bodily mechanism is specialised and our muscular power diffused in other directions, so that we could not actuate wings of sufficient area to carry us even if we had them.

M. de Lucy, a French naturalist, has shown that the wing-area of flying animals varies from about 49 square feet per lb. of weight in the gnat, and 5 square feet in the swallow, to half a square foot per lb. of weight in the Australian crane, which weighs 21 lb. and yet flies well. If he were to adopt the last or smallest proportion, a man weighing 12 stone would require a pair of wings each of them 14 feet long by 3 feet broad, or double the area of an ordinary room door, to carry him, without taking into account the weight of the wings themselves.

In flying birds there is a strong tripod arrangement to secure firm points of attachment for the wings, and a deep keel in the breast-bone, to which the large pectoral muscles are secured. Think of the wings I have described and the absence of pivots, keel, and muscles in man, and it will be tolerably obvious why he cannot fly, even with artificial wings.

But it might be contended that a man's strength is in his legs rather than in his arms, and that it is conceivable that a successful flying-apparatus might be made if adapted for the most, instead of the least, favourable application of his bodily strength.

According to D. K. Clark,[1] a labourer working all day exerts on an average ·13 horse-power. The maximum power of a very strong man for a very short time is ·46 horse-power.

According to Dr. Haughton,[2] the oarsmen in a boat-race of 1 mile, rowed in 7 minutes, exerted each ·26 horse-power.

Suppose we take the rowing case as the maximum maintainable for, say, 7 minutes by a man weighing 168 lb. Then in flight he would have to sustain a weight of

$$\frac{168}{\cdot 26} = 646 \text{ lb.}$$

per horse-power exerted, besides the weight of the apparatus.

Now, we shall find later (see p. 871) that no birds support even half that weight per horse-power which they have the power to exert, and that recent aëroplane experiments prove its impossibility. On the ground, therefore, that he is too heavy in proportion to his strength, it is clear that man is unfitted for flight, as well as because his limbs are not adapted for it.

It does not follow, however, that by aid of mechanisms apart from his own body, and worked by power independent of his own strength, man may not imitate, compete with, and even outdo the fowls of the air.

Let us consider a few facts showing what birds can do. A gannet hovers in the air above the sea. Suddenly he nearly closes his wings, swoops down, and with a splash disappears below the surface. Shortly after he reappears with a fish in his mouth, which he swallows in a few gulps; then, after swimming on the surface a little, he reascends into the air to repeat the operation.

The swallow rises into the air with a few rapid movements of the wings, then slides down as though on an aërial switchback, and then up again till he nearly reaches his original height, or he circles round by raising one wing, like a runner rounding a curve.

[1] *Rules, Tables, and Data*, pp. 719 and 720, by D. K. Clark.
[2] *Animal Mechanics*, by Dr. Haughton.

The condor vulture, which measures sometimes 15 feet across the wings, will fly upwards till quite out of sight.

A flock of cranes have been seen migrating at a height of three miles, and proceeding apparently without any movement of the wings.

The peregrine falcon will swoop down upon a partridge, and, missing it by a doubling movement of the latter, will slide upwards, thus converting his kinetic into new potential energy. He will then turn and descend again, this time securing his prey.

Mr. J. E. Harting, one of the principal British ornithological authorities, has, after careful investigation, arrived at the conclusion that the speed of falcons in full flight is about 60 miles per hour.[1]

Mr. W. B. Tegetmeier, another well-known authority, gives[2] the results of a number of experiments on the speed of homing pigeons, made under the auspices of the United Counties Flying Club in 1883. The average speed of the winner in eighteen races was 36 miles, and the maximum 55 miles per hour. The greatest distance flown was 309 miles.

The albatross, the largest web-footed bird, measuring sometimes 17 feet from tip to tip of wing, and weighing up to 20 lb., frequently accompanies ocean steamers from the Cape to Melbourne, a distance of 5,500 knots, without being seen to rest on the way.

An American naturalist, Mr. J. Lancaster, who spent no less than five years on the west coast of Florida,[3] in order to study the habits of aquatic and other birds which frequent these shores, arrived at the following conclusions, viz.—

Though all birds move their wings sometimes, many can remain indefinitely in the air, with wings extended and motionless, and either with or without forward movement. This he calls 'soaring.'

The wing-area of soaring birds varies from 1 to above 2 square feet per lb. of weight.

The larger the wings per lb. of weight, the greater the power to soar.

The heavier the bird, the steadier his movements.

Soaring birds always face the wind, which, if they do not move forward or downward, must not blow at a less speed than 2 to 5 miles per hour.

Mr. Lancaster specially watched a flock of buzzards about 30 feet above his head, waiting for him to leave the body of a dead porpoise. Their wings were about 8 feet from tip to tip, and their average weight about 6 lb. During three hours at mid-day, when the wind which they faced was very strong, they flapped their wings about twenty times each. Later, during two hours, when the wind had subsided, they never moved them at all.

Mr. Lancaster timed frigate birds, and found them able to go at the rate of 100 miles per hour, and that on fixed wings; he is of opinion that at all events up to that speed they can fly just as fast as they please. He says, further, that the same birds can live in the air a week at a time, night and day, without touching a roost, and that buzzards, cranes, and gannets can do the same for several hours at a time.

The observed facts relating to the phenomena of flight are still but very imperfectly understood. That a bird should be able to maintain a downward pressure on the air sufficient to counteract the effect of its own weight, and a backward pressure sufficient to force itself forward at such speeds as I have named, seems wonderful enough when it is known that it continuously operates its wings. But that it should be able to do the same without any muscular movement at all is almost incomprehensible. It seems to be an instance of the suspension of the laws of gravity and of the existence of cause without effect, and of effect without cause. It is not a case of flotation, like a balloon, for any bird falls to the earth like a stone when shot. Mr. Lancaster suggests that the bird's own weight is the force which enables him to counteract the effect thereof, but this explanation is, I confess, beyond my comprehension.

[1] *Field*, December 5, 1891, p. 856. [2] *Ibid.*, January 22, 1887, p. 114.
[3] 'Problem of the Soaring Bird,' *American Naturalist*, 1885, pp. 1055–1162.

It seems to me that for every pound of his weight pressing downwards there must be an equivalent force pressing upwards. This can be produced only by his giving downward motion to the air previously at rest, or by his arresting previous motion of air in an upward direction. The latter alternative involves the supposition that the air-currents which soaring birds face are not, as Mr. Lancaster believes, always horizontal, but must have, to some extent, an upward direction. If a parachute were falling in a current of air, which was moving upwards at the same rate as the parachute fell, it would obviously retain its level, yet gravity would be acting. So, if a bird with extended wings were sliding down a stream of air which was tending upwards at the same angle and same velocity, the phenomenon of soaring would be produced.

Weight of Birds in Relation to their Bulk.—It is generally believed that birds are lighter, bulk for bulk, than other animals, and that to this lightness they owe, in some degree, their power of flight and of floating on water. To account for this it is said that their bone-cavities are filled with air, and that some, though not even all, flying birds have small air-sacs under the skin. It is clear, however, that displacement of external air by air-filled cavities can only assist aërial flotation to an infinitesimal extent, unless highly heated. Such cavities would, however, help aquatic birds to swim, if situated under the immersed portion of their bodies, which is not always the case.

Some aquatic birds, such as swans, swim with head, neck, wings, tail, and half their bodies out of the water. The specific gravity of fishes and land animals is clearly about the same as water. For, when swimming, they can keep only a small portion of their heads above the surface, and that by continued exertion. Are, then, birds, in the substance of their bodies, less dense than other animals, although also composed of flesh, blood, and bone, and these components in similar proportions and of similar character and texture? If they are, then land animals might have been made lighter in proportion to their bulk or smaller in proportion to their weight than they have been. If they are not, how is it that some of them can swim and float high out of the water?

Having an opportunity recently of inspecting a large wild, or whooper, swan, I ascertained its weight to be 14 lb. I noticed that the whole of the under-part of the body, which would be immersed when swimming, was covered with feathers and underlined with down to an average depth of not less than $1\frac{1}{2}$ inch, or, when closely pressed, say, $1\frac{1}{4}$ inch. The immersed surface I estimated at $1\frac{1}{2}$ square foot. The weight of water displaced by this feather and down jacket, and the consequent extra buoyancy produced thereby, was no less than 9·78 lb. This would account for two-thirds of the bird's body being out of water when swimming, even if the body were of the same specific gravity as water.

I next procured a freshly-shot wild duck, which weighed $2\frac{1}{2}$ lb., and placed it in a tank of sea-water. It floated. I found the area of its immersed surface to be 54 square inches, and the average depth of its under-feathers and down to be $\frac{3}{4}$ inch. The water displaced by this envelope would weigh 1·5 lb., and would support three-fifths of its entire weight. I then had it denuded of all its feathers and down, and again placed in the tank. It then slowly sank to the bottom.

These experiments, so far as they go, seem to prove conclusively that birds are not lighter, bulk for bulk, than other animals, but, on the other hand, about the same specific gravity, and that their floating power lies entirely in the thick jacket or life-belt with which nature has furnished those, and those only, which are intended to swim.

Inasmuch, therefore, as the specific gravity of the actual bodies of all animals appears to be about the same, there is no reason to believe that any could have been constructed of lighter material or to lighter design.

Weight in Relation to their Energy.—But notwithstanding this uniformity of specific gravity, there remains the curious fact that flying birds can exert continuously about three times the horse-power per lb. of weight that man can—and, indeed, about three times what is possible for the horse.[1] This marvellous flow of energy in proportion to weight is probably due to rapidity of limb-action rather

[1] See pp. 868 and 871.

than to increase of muscular stress. I have timed sea-gulls and found them to flap their wings two hundred times per minute when flying at about 24 knots per hour, and have estimated eider-ducks, making about 36 knots per hour, to be flapping their wings five hundred times in a minute. I say 'estimated,' for their movements are too rapid for precise counting. This outpouring of energy, which seems to me to be unequalled in terrestrial animals, is nevertheless maintained by birds for indefinitely long periods of time.

A proportionately increased rate of combustion and renovation of tissue as well as of food-consumption are necessary consequences. The higher temperature of the bodies of birds, as compared with other animals,[1] and the well-known voracity of those which, like sea-birds, are almost continuously on the wing, are circumstances which seem to point to the same conclusion. It is confirmed by what we know of steam and other motors. For instance, if a steamship were so built and proportioned that a ton of coal per hour consumed in the boilers would maintain the pressure at 100 lb. per square inch and produce 1,000 horse-power at the propeller; and then if, without other alteration, firing was slackened until the steam fell to 50 lb. per square inch, and there maintained, it is clear that the horse-power produced would be greatly lessened, and so would the temperature of the steam in the boilers, steam-pipes, and cylinders. Thus, other things being equal, the temperature of the steam would rise and fall with the energy given forth by the mechanism.

The suggestion is that the higher temperature of birds, as compared with other animals, is similarly connected with their superior power of producing and maintaining energetic effort.

AËRIAL NAVIGATION.

Let us now consider what man has done, and may be able to do, in aërial navigation by aid of contrivances which, as in the case of railway locomotives and ocean steamers, are propelled by a power other than that of his own body.

The scientific world is greatly indebted to Mr. Hiram S. Maxim, of London, for recording in a clear and readable form the present position of aëronautic mechanisms.[2] So far, the only contrivances which have been fairly successful are balloons, which, unlike birds, depend on atmospheric displacement for their power of sustaining weight or rising or falling.

In balloon experiments our French neighbours have led the way, from the first attempt of the Montgolfier brothers in 1783. During the last twenty years they have made numerous experiments and substantial improvements. Captain Renard and other officers of the French Army have constructed a fish-shaped apparatus, and inflated it with hydrogen. It is driven by an electric motor of $8\frac{1}{2}$ horse-power, and has sufficient buoyancy to carry two aëronauts and all necessary accessories. In fair weather Captain Renard has succeeded in travelling at the rate of $12\frac{1}{4}$ miles per hour, in steering in any direction, and even in returning to his point of departure. The balloon, it is said, always keeps level, and so far there have not been any accidents; but no expedition has been attempted in wet or windy weather.

Except that a more powerful motor, going at a higher speed, might be fitted to such an apparatus, Mr. Maxim thinks that it is as near perfection as is ever likely to be reached by a machine depending on aërial flotation. He proceeds to give an account of some experiments made by Professor S. P. Langley, of the Smithsonian Institute, Washington, and of others by himself, to ascertain how much power is required to produce artificial flight by means of aëro-planes, after the manner of birds, and whether such power can be obtained without exceeding the weight which it would itself sustain.

[1] *Chambers's Encyclopædia*, 'Bird' and 'Animal Heat'; *Lehrbuch der Zoologie*, by Professor Hertwig, p. 538.

[2] 'Progress in Aërial Navigation,' by Hiram S. Maxim, *Fortnightly Review*, October, 1892.

He says that heavy birds, with relatively small wings, carry about 150 lb. per horse-power exerted, and birds such as the albatross and vulture probably about 250 lb. Professor Langley, with small slanting planes, was able to carry 250 lb. per horse-power exerted; and Mr. Maxim, using heavier weights in proportion to plane-area, 133 lb. per horse-power, and using lighter ones, nearly the same as Professor Langley.

Mr. Maxim has lately devoted his energies to constructing a motor which should meet the requirements of the case, and has succeeded, he says, in producing one—a steam-engine burning naphtha and with atmospheric condenser, within a total weight of 8 lb. per horse-power. He thinks, however,[1] that by using light naphtha and its vapour in the boiler instead of water, as well as in the furnace as fuel, a weight as low as 5 lb. per horse-power may be reached.

Meanwhile Professor Langley's ideas have been embodied in an experimental flying-machine, a drawing and description of which will be found in the 'Daily Graphic' for July 1, 1893. The body, which resembles that of a bird and is 15 feet long, contains the propelling machinery in duplicate. The wings, which are 40 feet across, are of China silk spread on a tubular framework, stiffened with wire trusses. The boilers use liquid fuel and contain a highly volatile fluid. The capabilities of the machine have not yet been practically tested.

Promising as are the results hitherto obtained, they are as yet far from placing us on a level with birds in power to utilise the atmosphere as a navigating medium. The absolutely necessary power of delicate guiding, in rising, falling, and turning, whatever the direction or force of the wind, has yet to be considered and worked out. What would happen in case of a temporary breakdown of the aëro-plane machinery we shudder to think of.

An important step has been effected by the discovery that parachutes with tubular orifices at the top are comparatively safe appliances for descending to the earth from indefinitely high altitudes. Perhaps it may be arranged that each aëronaut should be able, at a moment's warning, to gird himself with one of these as with a life-belt on board ship, and so descend in safety, or one or more automatically opening in case of disaster might be fitted to the aëro-plane as a whole.

EVENTUAL EXHAUSTION OF FUEL-SUPPLY.

I have still to refer to one other question, the consideration of which must always give rise to very serious thoughts. We have seen that the decisive victories which, in modern times, man has gained over matter and over other animals have been due to his use of power derived from other than animal sources. That power has invariably proceeded from the combustion and the destruction of fuel, the accumulations of which in the earth are necessarily limited.

Mechanical appliances, involving the consumption of fuel, have, for a century at least, been multiplying with alarming rapidity. Our minds have been set mainly on enlarging the uses and conveniences of man, and scarcely at all on economising the great sources of power in nature, which are now for the most part its fuels. Terrible waste of these valuable stores is daily going on in almost every department of use. Once exhausted they can never be replaced. They have been drawn upon to some extent for 1,000 years, and extensively for more than 100. Authorities say that another 1,000 years will exhaust all the more accessible supplies. But suppose they last 5,000 years—what then? Why, then, as far as we can at present see, our only motive-powers will be wind and water and animals, and our only mode of transit, sailing and rowing, driving, cycling, riding, and walking.

Sir Robert Ball has estimated that in not less than 5,000,000 and not more than 10,000,000 years the sun will have become too cold to support life of any kind on this planet. Between the 5,000 years when fuel will certainly be exhausted and the 5,000,000 years when all life may be extinguished, there will still be 4,995,000 years when, according to present appearances, man will have to give up his hardly-earned victories over matter and other animals, and the latter will again surpass him, each in its own element, because he has no fuel.

[1] *Engineer*, January 13, 1893, p. 28.

CONCLUSION.

Leaving to our posterity these more remote troubles, we may, I think, justly draw from the entire discussion the conclusion that we have still a great deal to learn from mechanisms as they exist in nature. Great as have been the achievements of man since he first began to study mechanical science, with a view to directing the great sources of power in nature for his own use and convenience, the entire field of research is by no means yet fully exhausted. We must continue to study the same science with undiminished ardour. In so doing we shall do well to bear in mind that success can be achieved only by the patient, accurate, and conscientious observation of the great facts of nature, which are equally open to us all and waiting for our attention; and by drawing correct inferences therefrom, and by applying such inferences correctly to the fulfilment of the future needs and destiny of our race.

The following Papers were read:—

1. *On the Automatic Balance of Reciprocating Mechanism.* *By* W. Worby Beaumont, *M.Inst.C.E.*

[Ordered by the General Committee to be printed *in extenso* among the Reports. See p. 665.]

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2. *On Lace Machinery.* *By* E. Doughty.

The commencement of the machine for making lace may be dated about 1764, when the old-fashioned stocking machine had been in existence about 200 years, about which time certain discoveries and improvements were made which enabled it to produce a net, at that time considered to be a great achievement, thus making the stocking machine virtually the first lace machine. In the course of the next few years various other improvements by skilful mechanics were made, which ultimately ended in producing a very useful net for embroidering purposes, finding employment for a large number of machines, as well as women and girls.

Very slow progress was made in the development of invention; but this is, perhaps, not much to be surprised at, considering that the ordinary mechanical tools in use were of the simplest description: there were no labour-saving self-acting tools with a steam engine for motive power to be found in any workshop then, and every tool, except files, had to be made by the workman himself, who also had to make every screw, bolt, and nut that he required.

The absolute necessity to supply himself with nearly every one of his requirements made the mechanic of that time a man of great resources, and contributed very much to his inventive faculties. At that time nearly every part of the machine was constructed of wrought iron, except the large framework, which was made of wood, cast iron being almost unknown then in machine making.

Further developments of the stocking machine led to the making of the warp machine, which had many details in common with its original, though very different in some respects. At one time great numbers of warp machines were employed in making a very useful cloth with which our sailors were clothed for years. Similar cloth has come into use again the last ten years under the name of Stockinette, being very elastic.

But a net was wanted, like that made by hand on the Continent, called Brussels net. After many trials by inventors Heathcote succeeded in making the exact net itself, and resulted in making his fortune, though it ruined hundreds of machine-owners who made net that had previously been used for the same purpose. Heathcote's machine was protected by patents, which many tried to evade by making the net on other machines. One man named Leavers originated a different machine, which after many alterations has come down to our time as the most useful lace machine we have.

Another machine was developed out of the plain net machine for making lace curtains.

A number of small details of machines were exhibited showing the relative differences of the old and the new.

3. *On Knitting Machinery.* *By* CHAS. R. WOODWARD.

The paper opens with historical references to the early forms of machinery for knitting, and shows what enormous strides have been made in improving their mechanical design and construction, what great progress in loop-forming capacity—advancing from 500 to 500,000 loops per minute—and how large and varied is the present scope of the trade, embracing, as it does, not only all forms of knitted underwear, but also stockinette cloth, astrachans, Cardigan jackets, Tam-o'-Shanter caps, down to bags in which to import foreign mutton. The new era in the making of stockings is next specially dwelt on and the main reasons given for the return to domestic machinery, among which are its cheapness, the low rate of wages for which country people will work, the fact that the goods require so little finishing that manufacturers have no factory expenses, and that much more comfortable socks and stockings are produced on these machines than on earlier types. The attempts recently made to successfully compete with the domestic machinery are next mentioned, the cosmopolitan spirit of Nottingham machinists shown in their introducing American machines into England, chief among which machines are the 'Shaw,' 'Scott & Williams,' and 'Aiken' machines, on which one girl will knit from fifty to eighty dozen pairs of half-hose per week, but which, unlike their rivals, are confined to the making of plain, *i.e.*, not ribbed fabrics. The probable lines of future development, though somewhat difficult to forecast, are indicated, and may be summarised thus:—Machinery which will work either by foot-pedals or steam power, and in which the narrowing, widening, changing of ribs, and forming of heels, toes, &c., will be manipulated by hand in a similar manner to that in which a typewriter is worked.

4. *On Lace and Hosiery Machinery.* *By* Professor W. ROBINSON.

FRIDAY, SEPTEMBER 15.

The following Reports and Papers were read:—

1. *Third Report on the Development of Graphic Methods in Mechanical Science.* *By* Professor H. S. HELE SHAW, *M.Inst.C.E.*—See Reports, p. 573.

2. *Report on Determining the Dryness of Steam in Boiler Trials.* See Reports, p. 572.

3. *On Thermal Storage by Utilisation of Town Refuse.* *By* C. C. KEEP.

4. *On the Disposal of Refuse.* *By* WILLIAM WARNER, *A.M.I.C.E.*

The treatment of refuse upon scientific principles was commenced by Mr. Alfred Fryer eighteen years ago.

Dry house refuse, mixed refuse, excrementitious matter, and sewage refuse treatment had been in the experimental stage for some time, but no one had shown

that it was possible to deal with these objectionable matters without creating a nuisance. The appliances then introduced were only used at a very heavy cost to ratepayers.

Although most of Mr. Fryer's inventions dealt with refuse in a divided form, as resulting from the introduction of the pail system, he also provided for the treatment of refuse from middens.

The pail system was then believed to be the right thing by most sanitarians, and Mr. Fryer's attention was turned to the pure excrementitious matter collected from pail closets.

The author referred to the crude and unsatisfactory methods in use. The middens were built above the ground level, and had only capacity to allow of small accumulation of refuse. It was found by experiments that excrementitious matter, when kept entirely separated, would produce a very valuable manure, which is worth at the present time 6*l.* per ton, and those towns treating it in the best apparatus had gained a fair revenue. Towns situated in agricultural districts are able to dispose of their sewage sludge, after pressing it, at a price which covers the cost of treatment; but many towns find it difficult to dispose of it. Experiments indicate that sewage sludge might be used successfully in the manufacture of bricks with specially designed machinery and kilns.

Road refuse is now much reduced by the good condition of the roads. Road sweepings when collected are not valuable as a fertiliser, and therefore are of little value to land, and will not burn even in destructors unless mixed with a large proportion of house refuse. Most authorities tip up the road sweepings upon waste land at considerable expense, and at the risk of creating a nuisance. There is, however, some value for this refuse, as the author has proved from a series of experiments conducted by him for a special committee of the Kensington Vestry. As to the disposal of house refuse for a town the size of Nottingham, producing approximately 400 tons per day, if the greater portion of the refuse were sent to farmers, and a small portion to a destructor, figures show that it is not possible to look forward to a large amount of power for electric lighting; it is even questionable whether the power thus generated could be applied usefully for that purpose. Supposing its refuse to have the average steam-producing qualities, about 300 horse-power will be obtained for an expenditure in labour of nearly 17*l.* per day, equal to over 5,000*l.* per annum.

With coal the cost of labour would be only 150*l.* per annum, and the cost of coal for fuel would be under 1,500*l.*; therefore, taking the refuse to cost nothing for delivery at a destructor works conveniently situated for producing electricity, the actual loss would amount to no less than 3,350*l.* per annum over coal fuel, and if they took into consideration the cost for repairs and interest on capital, this loss would be greatly increased.

Looking these facts into the face electric light produced by burning refuse could only show economical results in very exceptional cases, and authorities should consider the matter carefully before launching into a scheme of this kind.

The author has estimated the cost of burning at 10*d.* per ton, but if the treatment would cost 1*s.*, the increased loss would be 1,245*l.* per annum, making a total loss of 4,590*l.* per annum.

Taking the comparison of burning refuse in different kinds of destructors, these figures should be taken carefully into consideration, as 1*d.* per ton more in the cost of burning means over 600*l.* per annum in a town the size of Nottingham.

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5. *On Warming and Ventilation.* *By* FRANK ASHWELL, *M.I.M.E.*

The subject of warming and ventilation has been chosen by the author, as he is of opinion it is not yet so fully and generally studied as its importance demands, and he trusts the remarks which he will have to offer, supported as they are by very considerable practical experience, may prove of some interest. The principle of *mens sana in corpore sano* is as true to-day as ever, and with improved conditions of life the mind will have more chance to develop itself. The author contends

that a great advance has been made in the last year or two in the ventilation of large public and private buildings, to which class of buildings he will more particularly confine himself, and that if only a sufficient—by no means extravagant—amount of money is provided for it, some really definite results can be guaranteed.

It will not be necessary here to give an elaborate statement why it is necessary to provide for a proper supply of heat and pure air to our schools and public buildings; this has to some extent been done in the paper itself, which has been printed for circulation, and which may be referred to; but the author would like to point out at once that, in his opinion, no scheme of ventilation is complete which does not provide at the same time for the warming of the incoming air.

The various methods of ventilation may be grouped under two heads, viz., ventilation by natural means and ventilation by artificial or mechanical means.

Not much need be said here about natural ventilation, as it is now almost generally admitted that it is not suited for the ventilation of large public or private buildings, and in the future remarks attention will only be paid to mechanical ventilation, which will be subdivided again into mechanical ventilation by extraction (Vacuum system) and mechanical ventilation by impulsion (Plenum system).

The author's firm has had the good fortune to carry out a large number of ventilation schemes in various parts of the country, in which either the one or the other system or combinations of the two have been employed, some of which have been described in the paper at considerable length with the aid of eight diagrams; and he has come to the conclusion that, where the Plenum system can be employed, it is the best and most reliable of all the schemes of ventilation. It is assumed here that the scheme is well designed, well carried out, and well superintended, as no scheme whatsoever has a fair chance if these conditions have not been complied with.

One of the chief drawbacks of the Vacuum system is the uncertainty as to the purity of the incoming air, which will be drawn from that place that offers the least resistance to the passage of the air, and if badly constructed drains and sewers are near it may come from these.

Various objections have been raised against the Plenum system, and it is said to have been a failure in several cases. Of course the author cannot attempt to deal with installations put up by other gentlemen, but he would most emphatically say that his experience, which he has given in the paper, does not bear out those contentions, which not unfrequently have proceeded from quarters interested in ventilation by natural means.

All the objections cannot be considered here, but one or two of the more prominent ones will be dealt with shortly in the following remarks:—

1. As to breakdowns of the machinery.

It has been stated that if the engine breaks down no fresh air can be supplied till it is repaired.

In this respect the system stands on the same basis as all other so-called natural or mechanical schemes of ventilation, with this advantage, perhaps, that an accident to the machinery is at once noticed, and can be remedied without delay, whereas a breakdown in a patent cowl or some such appliance may not be noticed for a considerable time, as nobody attends to it.

It would, however, not be true to say that during a breakdown no fresh air at all will be supplied: this would only be the case during the warm weather, and then the openings of the windows will soon remedy it. During a breakdown in winter the hot air will still, to some extent, ventilate the rooms till the repairs are complete. This would be the condition of things in cases where no duplicate power is provided; but where this has been done, either by an extraction-tower, as at Nottingham, or a fan in the roof driven by an electric motor or by a duplicate engine at the air inlet, then no inconvenience at all will be felt during repairs; and though this course will prove somewhat more expensive at first, yet in the long run it will be the cheapest, and should be adopted in all cases where a temporarily reduced supply of fresh air entails hardship or danger to life. If this is done, then it may safely be asserted that the Plenum system is the most reliable system of ventilation.

2. As to scheme being too complicated.

It is quite true that any scheme of mechanical ventilation is more complicated than schemes of natural or so-called automatic ventilation; but Plenum schemes are by no means too complicated for successful working, as is proved by the experience gained in all parts of the globe.

To say that a natural scheme of ventilation is uninterruptedly at work all the year round is, to say the least, very misleading. It may be true that the atmosphere is always in motion; but then this motion may be so infinitesimally small at times as to cause no movement of air at all in our buildings—a state of affairs well known to all those who have to rely on this kind of ventilation.

The addition of the machinery is a safeguard for the regular supply of air in the proper quantities, and it is far better and wiser in all matters concerning so immediately the health of countless thousands as ventilation does to have a special man constantly attending to it, rather than leave it to itself, and all sorts of mishaps.

3. As to cost of scheme.

It is undoubtedly a most important matter to consider very carefully the cost of any ventilation scheme; but when comparing the expenses in connection with two different modes of ventilation for one building, great care must be taken to place the two schemes exactly, as far as this is possible, on the same basis as to the purity of air supplied, the quantity, the regularity, the convenience of working them, &c. If this is not done the results obtained will be utterly useless and misleading; but whenever this is done, and all the circumstances of the case considered, the author is confident that the expenses in connection with the Plenum system will not be found excessive. He has not prepared any figures, as he is of opinion general figures are frequently totally misleading, and for this reason he would recommend the consideration of the question of cost afresh for each particular case.

Concerning the value of other methods of ventilation, one of which it may be necessary to adopt where the Plenum system cannot be installed, the author wishes it to be understood that he by no means condemns them; that, on the contrary, each has its special advantages under certain conditions. In each individual case the ventilating engineer will have to investigate first its special circumstances and requirements, no two cases being alike, and then he will have to select his scheme accordingly.

In concluding his remarks on warming and ventilation the author desires to make it clear that his aim throughout has been to state his case fairly and fully, and he trusts he has succeeded in this; if, at the same time, he has been able to increase the interest in this question of vital importance, then all his efforts will be well repaid.

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6. *On Modern Watchmaking.* *By* T. P. Hewitt.

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7. *On Patent Percussive Tool for Calking, Chipping, Mining.* *By* J. MacEwan Ross.

The tool which the author now brings under notice is composed of few parts, and those are of the most substantial character.

The piston is a solid steel forging, truly turned and ground into the cylinder, so as to work or float quite freely, and this is the only moving part in the tool. It is about 3 in. long, slightly reduced at the centre where the actuating fluid is introduced into the cylinder.

The handle of the outer casing is cast hollow. One side is truly bored out and fitted with a brass piston valve covering the outlet of exhaust.

This valve is fitted with a trigger which when drawn back by the finger sets the tool in motion by allowing the exhaust to escape.

One man, by the use of this tool, can do as much work in a given time as five to ten men can do when calking by hand.

The principle upon which the tool works is as follows. The piston is turned

as before stated, reduced at the centre, leaving a collar on each end. The inside edges of these collars form the cut-off edges for pressure, while the outside edges govern the exhaust ports. When the piston is in its central position in the cylinder, there is a dead point for pressure and exhaust. But when the piston rests on the end of the chisel, and the tool is pressed up to its work, the inlet port is opened on the front side, and the exhaust port at the back end of the cylinder. Therefore, when the exhaust trigger valve is opened, a load of about seventy times the piston's mass acts on the end of the piston, and sends it at an enormous velocity, which carries it over the dead point until it is cushioned at the back end of the cylinder, and similarly on its return stroke until it hits the chisel head.

The tool also works equally well with steam, special provision being made to prevent the heat of the steam from inconveniencing the workman. The tool is now largely used for calking, and it has been applied with success to the operations of chipping and dressing plates and castings.

It is also capable of boring a 1-in. hole through sandstone at the rate of about 12 in. per minute, and through whinstone at about $4\frac{1}{2}$ in. per minute.

It is largely used by many of the leading railway companies, engineers, and shipbuilders throughout the country.

MONDAY, SEPTEMBER 18.

The following Papers were read:—

1. *On the Relative Cost of Conductors with Different Systems of Electric Power Transmission. By* GISBERT KAPP.

Owing to difficulties of insulation and flashing at the commutator, long-distance transmission of power by continuous current is not so practicable as by alternating currents, where the generating and receiving apparatus can easily be insulated to any desired degree. The working pressure is thus limited, not by the apparatus at either end, but by the difficulties of insulating the line, and in comparing various systems of power transmission it is necessary to place all on an equal footing as regards stress on the insulation of the line. Taking a transmission plant with continuous currents as the standard of comparison, and assuming in all cases the same distance, total power, efficiency, and safety against breakdown of the insulation, the author finds that the single-phase two-wire system of transmission by alternating currents requires double the weight of copper as compared with continuous currents. The same ratio applies to the double-phase alternating current sent over four wires, but if the system is worked with a common return (*i.e.*, employing only three wires), the weight of copper is increased to 2·9 times that of the equivalent continuous current system. This increase is due to the fact that by tying two of the conductors together the absolute potential between the other two and between either and earth is increased, and to get back to the original condition of stress on the insulation the working pressure has to be lowered. With the three-phase three-wire system the weight of copper is only 1·5 time that of the equivalent continuous current system, showing that as regards economy of copper the three-phase system has an appreciable advantage over the single and the two-phase systems.

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2. *On the Utilisation of Waste Water-power for Generating Electricity. By* ALBION T. SNELL.

On the Continent water-power is extensively used for driving electric plants, but in Great Britain, for a similar purpose, power is usually derived from the combustion of coal.

This difference in practice is partly the result, no doubt, of the relative supply

of water-power in the neighbourhood of places where electric plants would prove commercially profitable; but it is also largely due to the relative cost of fuel. We do not possess abundant natural sources of water-power in or near our large manufacturing districts, and even if we did it is not probable that with coal at the average price of the last ten years water-power would prove much cheaper when the capital invested, interest, and cost of maintenance of the electric plant were taken into consideration. But we may with reason pause to ask two questions: Will coal at such a price be always obtainable? And do we make the most of such water-power as we have and can profitably use? Let us look at the second question first. Liverpool is supplied with water from Lake Vyrnwy, in North Wales, the total difference of head being about 500 feet. There must be a considerable quantity of power in the conduit. Is any of it utilised? And if not, does the reason lie in the fact that fuel at present is so cheap? Could the Manchester Waterworks, which form a magnificent series of artificial lakes, be utilised to drive turbines and give electric energy for lighting the various towns in their vicinity? Again, the watershed behind Greenock has a fall of many hundred feet, and the water is only partly utilised to drive mills. These are only a few instances in which water-power might perhaps be advantageously used for driving turbine dynamos. There are, of course, numerous mountain streams which could be dammed, and thus converted into reservoirs for feeding turbines.

There is still much misconception on the part of the responsible advisers of manufacturers and mineral owners as to the possibilities of electricity for the transmission of power. But the experience gained during the last decade is gradually making itself felt, and the most conservative must admit it has given us the means of utilising natural water-power in a far more efficient manner than was formerly possible.

Various plants, typical of Continental practice, were then referred to by the writer. They differ widely, both as regards size, method, and details; but they are all designed on the broad lines of utilising waste water-power, and transmitting its energy electrically to towns where it can be usefully expended.

The writer says that alternate currents appear to be generally selected, perhaps, because they offer more advantages than direct currents for high pressures, and are generally more easily managed; and in several cases it has been deemed advisable to use a direct-current distribution with an alternate-current transmission, as at Cassel.

The Lauffen-Heilbronn plant is at present the only important instance of a rotary-current system, and there considerable difficulty is found in balancing the load on the two circuits.

In England there are only a few installations which derive their power from water, such as the small central station for lighting Lynmouth and Lynton, and a few private installations. A scheme, on [a large scale, for electrically lighting Worcester by means of power derived from the river Severn is in hand, and will, no doubt, lead to similar plants.

One of the most important instances of the application of water-power for electric power transmission in Great Britain is that at the Greenside Silver Lead Mines in Cumberland, which was designed by the writer about three years ago.

On the east slopes of Hellvelyn lies a small natural lake called the Red Tarn, and on the north-east the impounded water of Keppel Cove. Between the two waters rises the hill of Catstycam, at the base of which the two overflows join, and near to which the Greenside Silver Lead Mining and Smelting Company have erected their turbine-dynamo station. The water is led from an elevation of 1,750 feet above sea-level, and flows through an open watercourse $1\frac{1}{4}$ mile in length to a large reservoir, from which it is conveyed down the hill-side for a distance of 360 yards in 15-inch cast-iron pipes. The fall at the station is equivalent to a vertical head of 400 feet, and the effective horse-power is about 200.

The generating station contains one of Gilkes & Co.'s vortex turbines of 100 horse-power, driving a four-pole compound dynamo.

The electric current is conveyed by two bare copper conductors on poles for six furlongs, and then enters the mine at an elevation of 1,850 feet above the

sea-level. The conductors from this point are insulated and covered with lead. About three-quarters of a mile in the mine, or $1\frac{1}{2}$ mile from the dynamo, a 9-horse-power series motor is employed to wind ore from a set of sinkers. Further into the mine another quarter of a mile, and down 120 yards at the bottom level, is fixed another 9-horse-power motor, working a three-throw pump, forcing the water 360 feet in height.

About midway between these motors there is fixed a dynamotor, which reduces the pressure from 600 to 250 volts for working an electro-locomotive in the lowest day level of the mine, through which runs the water pumped from the 120-yards level and the whole of the water used by two hydraulic winding engines. Four horses formerly worked this level. The locomotive runs with twelve waggons, the total weight when loaded being eighteen tons, and does the work of the four horses with the greatest ease. The conductors in the level are phosphor bronze wire, and the current is fed to the locomotive by four contact pulleys.

The chief difficulty attending the use of water-power is the irregular and sometimes intermittent character of the supply, and hence it is necessary to exercise great care in judging the suitability of water for given work. This can be obviated to a large extent by building reservoirs and regulating the output according to the power required; but when lighting forms an important part of the scheme, secondary batteries may be used most advantageously. Accumulators act not only as reservoirs, but also as regulators, storing up excess of power, and giving it out when the prime power is insufficient or the turbines are stopped. They are therefore especially useful on installations for combined power and light when the water-power varies intermittently. And they may be made a source of economy when power is not required both by day and by night, and owing to the want of a suitable reservoir the water runs to waste during the idle period; then accumulators may be used to store the major part of this energy for electric lighting, metallurgical, or even power purposes.

It will be gathered that the writer is fully aware the small water-power of Great Britain can never show results equivalent to those obtained on the Continent; yet there is undoubtedly much water-power wasted here that is capable of being profitably utilised. His object is simply to call attention to the improved means of utilising water-power by the turbine dynamos, and to suggest that prompt measures be taken to conserve as much power as possible by a proper attention to the building of dams and reservoirs wherever this may be feasible; and that such power should be used if convenient, to the exclusion of coal, and, if not so, as an auxiliary power, the steam plant being used as a stand-by as much as possible. This proposal, if properly carried out, would decrease the total consumption of coal to a greater extent than is generally supposed, and would make a number of manufacturers less dependent upon it than they are to-day, even if it did not appreciably cheapen the cost of power. But in a number of favoured cases there can be no doubt that water-power properly applied would considerably decrease the cost of working, allowing a proportionate gain to both producer and consumer.

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3. *On a new Form of Variable Power-gear for Electric Railways and Tramways. By* W. WORBY BEAUMONT, *M.Inst.C.E.*

It is a matter of great importance on electrical railways and tramways that the maximum steam-engine power at work in the generating station should be as little above the mean load as possible.

It is found on electrical railways now at work that there is a great waste of power, and therefore of fuel, in consequence of the large consumption of current in getting the trains into motion by motors attached directly to the axles. On the South London Railway it is found that the power employed electrically in overcoming the inertia of the train is from 25 to 50 and 60 per cent. greater than that required to keep the train going.

Mr. J. H. Greathead, M.I.C.E., the engineer of this railway, has shown that if this could be avoided from 20 to 30 per cent. of the engine power which must

under present conditions be kept running might be shut down. The author shows this by diagrams representing the variation in the consumption of power in the working of this railway, as given by Mr. Greathead.

For several reasons the employment of geared locomotives is undesirable on railways, although single-reduction gearing is most generally adopted for tramways, and probably will remain best for that purpose. The noise made by high-speed gearing and the wear are both objectionable, otherwise a geared locomotive offers the means of overcoming, to some extent, the losses referred to.

In the paper the author shows how an intermediate course can be adopted which will entirely remove the loss of power at the generating station. The electric motor is placed directly on the driving-axle, but is reduced in size and power to more nearly that of the mean horse-power required on the road. This, for the greater part of the journey of a train from station to station, drives the axle upon which it is placed, at its own speed, just as those do which are now upon the South London Railway. The motor is, however, on a hollow spindle, which drives the axle, when starting a train, through the medium of a compact double clutch containing one pair of epicycloidal reducing wheels. The clutches are operated by electro-magnets or by fluid pressure.

The train or locomotive may by this means be started at from one-fourth to one-seventh of the speed of the motor. After a few seconds, the inertia of the train having been overcome, the motor, the clutch-gear, and the driving-axle are solidly coupled, and all move as one piece, the gearing only working during the starting of the train.

The motor may thus run idle upon the axle, or may drive the latter at one-seventh of its speed, or at its own speed. A breakdown leaves the locomotive in the condition of a gearless engine.

For tramcars similar apparatus is described in the paper, which will drive the car by a direct motor with starting ratio of gear of about six to one, or by single reduction gearing will drive the car either at the usual gear ratio of about four to one, or, for starting, at a ratio of about twenty-four to one.

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4. *On Self-exciting Armatures and Compensators for Loss of Pressure. By* W. B. Sayers.

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5. *On a Mechanical System of Electrical Conductors. By* E. Payne.

These conductors have been designed with the object of providing a system of mechanical conductors, constructed without the use of vegetable substances, which shall not be open to the objection sometimes urged against the wood-casing and covered wires usually employed for interior wiring, viz., that they are not composed of fireproof and imperishable materials like gaspipes, waterpipes, and other fixtures and fittings.

The author began to work out the details of the system in the autumn of 1890, in company with his partner, Mr. Carrington Smythe, and Mr. David Cook, who is now the engineer and general manager of the City of London Electric Lighting Company.

The conductors consist of tubes, strips, rods, or wires of copper separated from one another by insulators fixed at intervals, and usually made of glazed earthenware. It was our object to construct the conductors so that they could be made up in lengths in the workshop and sent out ready for erection.

The first experiments were made with tubes arranged on the concentric principle, and consisted of a copper rod or a tube filled with bare wires placed inside another tube; when this was not used as an earthed return these were placed inside a third tube which was used merely as a mechanical protection.

The chief mechanical difficulties that had to be got over were (1) the fixing of the insulators to the conductors, whether tubes, rods, or wires, so that they might be sent out in lengths or in coils ready insulated; and (2) the designing of suitable junctions and junction-supports for the outside tubes.

By using tubular strips of thin copper, not soldered or brazed along the edges, the author was able to fix the ring-shaped separators in position by having them made to fit tightly and forcing them over the tube, so that they were held by the outward spring of the metal.

He improved upon this method by making the inside or inner insulators to fit lightly inside the tube, so that the insulators were held in position by their mutual inward and outward pressure.

He next subdivided the outer tube into two or more separate strips, kept apart by projections on the insulators, so as to be able to run two or more circuits in one tube, using the central wire as a common return. For fixing the insulators to wires and strips two wires were passed through separate holes in insulators at intervals, the wires being afterwards twisted to hold the insulators in position. By employing a conductor or combination of conductors of non-circular section and passing them through non-circular holes of suitable size made in the insulators, and afterwards twisting the conductors, the insulators are fixed firmly in position. In all cases other wires may be drawn through other holes to form leads or returns for other circuits. Several circuits can thus be run in one tube, and a great deal of jointing is thus done away with. For jointing the tubes L- and T-shaped castings or stampings are used, which can be fixed over or round the ends of the tubes where they meet.

The author and his coadjutors have also designed and used a large number of junction-boxes made in parts and all interchangeable, so that they can be adapted to work with the fittings—ceiling-roses, switches, &c.—in daily use. Rows of lamps fixed on a tube and arranged on one or more circuits are convenient for lighting shop windows and showrooms, and for the footlights on the stage.

The tubes can be erected round the walls of a room like picture rods.

As the temperature of the interiors of buildings is usually higher than that of the air outside we do not meet with the fall in the insulation owing to condensation in the tubes, which is sometimes said to occur in underground conduits where bare conductors are run on insulators.

These conductors can be erected in hot places and in hot countries, where they are exposed to the heat of the sun without any fear of damage to the insulation. They are proof against the attacks of rats and mice when laid under floors, and if a conduit becomes red-hot there is nothing that will catch fire.

TUESDAY, SEPTEMBER 19.

The following Papers were read:—

1. *On Flashing Lights for Lighthouses.* *By* O. T. Olsen.

In the interest of the nautical world the author proposes a system for the improvement in the distinguishing characters of coast-lights and light-vessels throughout the world. Admiral Colomb introduced a system of flashing numerals for signalling over thirty years ago, which still remains open for the mercantile marine to adopt; Lord Kelvin investigated the lights of the coast some years ago, with a view to making them known by flashing the International Code letters: this has not been adopted, as the Morse code, which it would be necessary for every mariner to learn and remember, is too complicated. The author proposes that the numerals only should be used, and not the alphabet.

(1) All the principal lighthouses and light-vessels throughout the world should be arranged in numerical order, beginning with, say, the oldest or British lights. Allot to each light a number, beginning with 1,000, so that no less than four figures may be flashed, these numbers to be inserted in the Admiralty list of lights, and copied into all charts, sailing directions, almanacs, &c.

(2) Make each light flash its allotted number, and no other, by means of an automatic apparatus or clockwork as in use at present. The shortest and easiest

flashing system is that introduced by Admiral Colomb, which consists of ten figures, represented by short and long flashes, thus:—

1 .	2 . .	3 . . .	4	5 . . . . .
6 ——	7 . ——	8 —— .	9 . . ——	0 —— . .

The present flashing, occulting, intermittent, and revolving lights are capable of performing the services required by a slight alteration in the clockwork to give the necessary division of time, thus:—

A short flash, 1 second; an interval between two figures, 3 seconds; and an eclipse of nine seconds after each complete signal, followed by a steady light for the remainder of the 60 seconds.

Example.—To flash a light the number of which is 3,724 would occupy 39 seconds, and leave a bright light 21 seconds, the whole to occupy one minute, thus:—

	Seconds
Eclipse	1
Fig. 3	5
Eclipse	3
Fig. 7	5
Eclipse	3
Fig. 2	3
Eclipse	3
Fig. 4	7
Eclipse	9
Bright light	21
	60

	Seconds
No. 1111 would be the shortest, occupying only	23
Bright light	37
	60

	Seconds
No. 5555 would take the longest time to flash, viz., leaving—	55
Bright light	5
	60

This is the extreme range, and the whole can thus be performed in one minute, and the light to repeat this revolution every minute during the night.

In fog the author proposes that the numbers be given by a siren every minute, such siren to be confined strictly to lighthouses and light-vessels, and prohibited in the mercantile marine.

In adopting this system the mariner will become acquainted with the flashing system, and thus lay the foundation of an international flashing signal system for the mercantile marine, so much needed. The author believes that 999 sentences selected from the Commercial Code Book would be ample for all practical purposes.

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2. *On an Automatic Gem-separator.*
By William S. Lockhart, *M.I.C.E., M.I.M.E.*

The separator described was devised for the purpose of selecting precious stones from the worthless gravel with which they are associated without the intervention of hand-picking as now practised, thus avoiding the danger of loss by theft and other disadvantages. In South Africa, Burma, Siam, Ceylon, and other parts of the world the systems of washing vary to some extent. The earlier stages of these processes would take too long to describe, but all systems resolve themselves finally into the picking over of a concentrated deposit of clean washed gravel for the gems it may contain, and it is at this point that the separator comes in to perform what has hitherto been done by hand. When it is realised that the

proportion of gems to worthless pieces of mineral is not a percentage merely, but of one to many thousands, the utility of such a machine is obvious.

The concentrated gravel when washed is most carefully classified into sizes, beginning, for diamonds, at one-sixteenth of an inch, and increasing by sixteenths up to five-eighths of an inch, or still further if desired. Each size of gravel is fed into a separator adapted to suit it. The separator has no moving parts—and takes advantage, by means of a stream of water running through it, of the slight variation in specific gravity between the gems (3·5 to 4) and the worthless minerals (2·5 to 3). It is possible to separate such substances by immersing them in a prepared solution of high specific gravity, just as pebbles and chips may be separated in water; but there are practical difficulties about such a process, and the gem-separator described substitutes a moving current of water for the heavier solution, with the advantage that the process is continuous, the separated materials being deposited in their proper receptacles, those for the gems being guarded by locks.

The details of the machine are described, and a machine shown at work.

The operations of the machine are not confined to gems. The separation of any minerals from their gangue, provided always there is a slight difference in specific gravity, may be effected, and the machine will work on broken material in a dry or merely wetted state or on slimes run in with a stream of water.

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3. *On some Experiments with Ventilating Fans or Air-propellers.* *By* WILLIAM GEORGE WALKER, *M.Inst.M.E.*

These experiments have reference to those ventilating fans or air-propellers of the screw-propeller type used for low-pressure ventilators.

The primary object of the experiments was to test the efficiency of fans or air-propellers, differing only from each other in the cross-section of their blades, which section chiefly referred to the rearward or non-propelling face of the blades or vanes.

The first series of experiments were made with air-propellers 14 in. diameter and 21 in. pitch, and of two, three, and six blades respectively. Each propeller was tried at progressive revolutions, varying from 500 up to 2,000 per minute. The blades were composed of sheet brass $\frac{1}{16}$ in. thick.

The second series were made with the same propellers, but having a curved convex protuberance fixed to the back surface of the blades, forming a section which is a hollow plano-convex form, the convex surface constituting the non-propelling surface, or backs of the blades.

In all cases the efficiency of the blades was increased by the addition of the convex surface; in some cases the number of cubic feet per revolution was nearly doubled, the power being the same in each case.

Some further comparative experiments were made with fans of 2 feet in diameter, and with blades of different sectional form, viz., (1) flat blades, (2) curved blades, (3) helical blades, (4) flat blades with round protuberance fixed at back, (5) curved blade with round protuberance fixed on, also other sections.

The angle of the blades and the area were the same in each case. The experiments most distinctly showed that a very great gain was obtained by the use of the convex surface, and that the best results were obtained with a section of concavo-convex form.

The reason of the results may perhaps be explained from the 'Stream Line' principle. It seems that the convex surface at the back tends to fill up or destroy the partial vacuum which exists at the back of each revolving blade. The existence of an eddy in the wake of each blade must increase the rotary motion of the air, caused by air passing through the propeller clinging or tending to rush into the partial vacuum.

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4. *On the Testing Machine and Experimental Steam Engine in the Engineering Laboratories of University College, Nottingham.* *By* Prof. W. ROBINSON.

Section H.—ANTHROPOLOGY.

President of the Section—R. Munro, M.A., M.D.

THURSDAY, SEPTEMBER 14.

The President delivered the following Address:—

The science of Anthropology, in its widest sense, embraces all the materials bearing on the origin and history of mankind. These materials are so comprehensive and diversified, both in their character and methods of study, that they become necessarily grouped into a number of subordinate departments. From a bird's-eye point of view, however, one marked line of demarcation separates them into two great divisions, according as they relate to the structure and functions of man's body, or to the works he has produced—a classification well defined by the words *anthropology* and *archæology*. The former, in its limited acceptation, deals more particularly with the development of man—his physical peculiarities, racial distinctions, linguistic manifestations, mental endowments, and, in short, every morphological or mental modification he has undergone amidst the ever-changing phenomena of his environments. The latter, on the other hand, takes cognisance of man merely as a handicraftsman. During his long journey in past time he has left behind him, scattered on the highways and byways of primeval life, numerous traces of his ways, his works, his culture, and his civilisation, all of which fall to be collected, sorted, and interpreted by the skilled archæologist. In their general aspects and relationship to each other most of the leading subjects in both these branches of the science have already been expounded, in the presidential addresses of my predecessors, by men so distinguished in their respective departments that they have left little to be said by anyone who attempts to follow in their footsteps. There is, however, one phase in the progressive career of man which has not hitherto been so fully illustrated as the subject appears to me to merit. I refer to the direct and collateral advantages which the erect position has conferred on him; and to this I will now briefly direct your attention, concentrating my observations successively on the following propositions:—

(1) The mechanical and physical advantages of the erect position.

(2) The differentiation of the limbs into hands and feet.

(3) The relation between the more perfect condition of these organs and the development of the brain.

In the process of organic evolution it would almost appear as if nature acted on teleological principles, because many of her products exhibit structures which combine the most perfect adaptation of means to ends along with the greatest economy of materials. This is well exemplified in some of the structural details of the organs of locomotion in which many of the so-called mechanical powers may be seen in actual use. The primary object of locomotion was to enable the organism to seek its food over a larger area than was attainable by a fixed position. The acquisition of this power was manifestly so advantageous to animal life that

the principles by which it could be effected became important factors in natural selection. I need not here dwell on the various methods by which this has been accomplished in the lower forms of life, but proceed at once to point out that in the higher vertebrates the problem resolved itself into the well-known mechanism of four movable limbs, capable of supporting and transporting the animal. As these quadrupedal animals became more highly differentiated, in virtue of the necessities of the struggle for life and the different and ever-varying conditions of their surroundings, it followed that the limbs became also modified so as to make them suitable, not only for locomotion in various circumstances, but also useful to the animal economy in other ways. Hence they were subjected to an endless variety of secondary influences, which finally adapted them for such diverse purposes as swimming, flying, climbing, grasping, &c. The anterior limbs, owing to their proximity to the head, were more frequently selected for such transformations as may be seen, for instance, in the wings of a bird. But whatever modifications the fore limbs may have undergone, no animal, with the exception of man, has ever succeeded in divesting them altogether of their primary function. This exceptional result was due to the erect position, which necessitated a complete division of labour as regards the functions of the limbs—the two anterior being entirely restricted to manipulative and prehensile purposes, and the two posterior exclusively devoted to locomotion. Coincident with this notable specialisation of their function a new field for advancement was opened up to man, in which intelligence and mechanical skill became the leading factors in his further development.

Man is thus distinguished from all other animals by the fact that, in the normal position of walking or running, he carries his body upright, *i.e.*, with the axis of the vertebral column perpendicular, instead of horizontal or oblique. In this position all its parts are so arranged as to require a minimum amount of exertion in the performance of their functions. If any of the other higher vertebrates should ever assume an erect attitude it can only be maintained temporarily, and its maintenance involves an additional expenditure of force. In a certain sense a bird may be looked upon as a biped, but there is this distinction to be drawn between it and man, viz., that the former has not only its body balanced obliquely on its two legs, but also its fore limbs converted into special organs for motion in the air. The anthropoid apes hold an intermediate position, and so carry their body in a semi-erect attitude. But this shortcoming in reaching the perfectly upright position, however slight it may be in some of these animals, represents a wide gap which can only be fully appreciated by a careful study of the physiological and psychological phenomena manifested in their respective life-functions.

Everyone acquainted with the ordinary operations of daily life knows how much labour can be saved by attention to the mere mechanical principles involved in their execution. In carrying a heavy load the great object is to adjust it so that its centre of gravity comes as nearly as possible to the vertical axis of the body, as otherwise force is uselessly expended in the effort to keep the entire moving mass in stable equilibrium—a principle well exemplified by the Italian peasant girl when she poises her basket of oranges on her head. Once upon a time a powerful waterman, accustomed to use buckets double the size of those of his fellow-watermen, had the misfortune to have one of them broken. As he could not, then and there, get another bucket to match the remaining one, and wishing to make the best possible use of the appliances at hand, he replaced the broken vessel by one half its size. He then filled both with water and attempted to carry them, as formerly, attached to a yoke, one on each side of him. But to his astonishment this arrangement would not work. The yoke became uneven, and the effort to keep it balanced on his shoulders was so troublesome that he could not proceed. This emergency led to serious reflection, but, after some experimental trials, he ascertained that, by merely making the arm of the yoke on which the small bucket was suspended double the length of the other, he could carry both buckets without inconvenience.

But let me take one other illustration. Suppose that two burglars have concocted a plan to rob a richly-stored mansion by getting access to its rooms through

the windows of an upper story. In order to carry out this design they secure a ladder, easily transported by the two together though too heavy for one. So, bearing the ladder between them one at each end, they come to the house. After a considerable amount of exertion they succeed in placing the ladder in an upright position against the wall, and then one of the men mounts its steps and enters the house. The man left outside soon realised that, once the ladder was balanced perpendicularly, he himself could then easily control it. Moreover, he made the discovery that by resting its weight on each leg alternately, he could gradually shift its position from one window to another. Thus there was no interruption or limit to the extent of their depredations. Experience quickened their perceptions, and ultimately they became adepts in their respective departments—the one in the art of moving the ladder, and the other in the science of the nimble-fingered gentry. The division of labour thus practised by these two men accurately represents what the attainment of the erect attitude has accomplished for man by setting free his upper limbs from any further participation in the locomotion of his body.

The continued maintenance of this unique position necessitated great changes in the general structure of the body. The solution of the problem involved the turning of the ordinary quadruped a quarter of a circle in the vertical plane, thus placing the axis of the spine perpendicular, and consequently in line with the direction of the posterior limbs; and to effect this the osseous walls of the pelvis underwent certain modifications, so as to bear the additional strain put upon them. Stability was given to the trunk in its new position by the development of special groups of muscles, whose powerful and combined actions render to the movements of the human body their characteristic freedom and gracefulness. The lower limbs were placed as widely apart as possible at their juncture with the pelvis, and the thigh- and leg-bones were lengthened and strengthened so as to be capable of supporting the entire weight of the body and of transporting it with due efficiency when required. The spinal column assumed its well-known curves, and the skull, which formerly had to be supported by a powerful muscle attached to the spinous processes of the cervical vertebræ (*ligamentum nuchæ*), moved backwards until it became nearly equipoised on the top of the vertebral column. The upper limbs, instead of taking part in their original function of locomotion, were now themselves carried as flail-like appendages, in order to give them as much freedom and range of action as possible. The shoulder-blades receded to the posterior aspect of the trunk, having their axes at right angles to that of the spine. Further, like the haunch-bones, they underwent certain modifications, so as to afford points of attachment to the muscles required in the complex movements of the arms. In the pendulous position each arm has its axis at right angles to that of the shoulder, but by a common muscular effort the two axes can be readily brought into line. The elbow-joint became capable of performing the movements of complete extension, flexion, pronation, and supination—in which respects the upper limb of man is differentiated from that of all other vertebrates.

But it is in the distal extremities of the limbs that the most remarkable anatomical changes have to be noted. The foot is virtually a tripod, the heel and the ball of the great toe being the terminal ends of an arch, while the four outer digital columns group themselves together to form the third, or steadying, point. The outer toes thus play but a subordinate part in locomotion, and, as their prehensile function is no longer of use, they may be said to be fast approaching to the condition of rudimentary organs. The three osseous prominences which form this tripod are each covered with a soft elastic pad, which both facilitates progression and acts as a buffer for deadening any possible shock which might arise in the course of running or leaping. The chief movement in the act of progression is performed by an enormously developed group of muscles known as the calf of the leg, so characteristic of man. The walker is thereby enabled to use the heel and the ball of the great toe as successive fulcrums from which the forward spring is made, the action being greatly facilitated by that of the trunk muscles in simultaneously bending the body forwards. The human foot is thus admirably adapted to be both a pillar for supporting the weight of the body and a lever for mechanically impelling it forwards. Hence the amount of energy expended in progression is

reduced to a minimum, and when estimated proportionally to the size of the body it is believed to be considerably less than that requisite for the corresponding act in quadrupeds.

The anatomical changes effected in the extremity of the upper limb are equally radical, but of a totally different character and scope. Here we have to contemplate the transformation of the same homologous parts into an apparatus for performing a series of prehensile actions of the most intricate character, but among which neither locomotion nor support of the body forms any part whatever. This apparatus is the human hand, the most complete and perfect mechanical organ nature has yet produced. The fingers have become highly developed, and can be opposed singly or in groups to the thumb, so as to form a hook, a clasp, or a pair of pincers; and the palm can be made into a cup-shaped hollow, capable of grasping a sphere. Nor is there any limit to the direction in which many of these manipulations can be performed without any movement of the rest of the body. For example, a pencil held by the thumb and the two forefingers, as in the act of writing, can be placed in all the directions of space by a mere act of volition.

The position of such a perfect piece of mechanism, at the extremity of a movable arm attached to the upper part of the trunk, gives to man a superiority in attack and defence over all other animals, on the same principle as a soldier finds it advantageous to fight from higher ground. Moreover, he possesses the power to perform a variety of quick movements, and to assume attitudes and positions eminently adapted for the exercise of that manipulative skill with which he counteracts the superior brute force of many of his antagonists. He can readily balance his body on one or both legs, can turn on his heels as if they were pivots, and can prostrate himself comfortably in the prone or supine positions. As the centre of gravity of the whole body is nearly in line with the spinal axis, stable equilibrium is easily maintained by the lumbar muscles. Altogether we have in his physical constitution a combination of structures and functions sufficiently unique in its *tout-ensemble* to place man in a category by himself. But at the same time we must not forget that all his morphological peculiarities have been brought about without the destruction of any of the primary and typical homologies common to all the higher vertebrates.

Turning now to the brain, the undoubted organ of the mind, we find, in its intellectual and psychical manifestations, a class of phenomena which gives to man's life-functions their most remarkable character. However difficult it may be for our limited understanding to comprehend the nature of conscious sensation, we are forced to the conclusion that the act invariably takes place through the instrumentality of a few nerve-cells, whose functional activity requires to be renovated in precisely the same manner as the muscular force expended in walking. The aggregation of such cells into ganglia and nerves, by means of which reflex action, consciousness, and a variety of psychical phenomena take place, is found to permeate, in a greater or less degree, the whole of the organic world. In the higher vertebrates the seat of these manifestations is almost exclusively confined to an enormous collection of brain substance placed at the upper end of the vertebral column, and encased in a complete osseous covering called the skull. We learn from numerous experimental researches, carried out by physiologists in recent years, that the brain is a dual organ, consisting of a double series of distinct ganglia and connected to some extent by a complex system of nervous tissues, not only with each other, but with the central seat of consciousness and volition. But the difficulty of determining the nature of its functions, and the *modus operandi* of its psychological manifestations, is so great that I must pass over this part of the subject very lightly indeed. The conditions of ordinary reflex action require that a group of muscles, by means of which a particular bodily movement is effected, shall be connected with its co-ordinating ganglion by an afferent and an efferent system of nerves. Impressions from without are conveyed by the former, or sensory nerves, to the central ganglion, from which an impulse is retransmitted by the motor nerves, and sets in operation the muscular force for producing the required movement. But this efferent message is, in many cases, absolutely controlled by volition; and not only can it prevent the muscular action from taking place, but it

can effect a similar movement *de novo* without the direct intervention of external impressions at all. Now it has been proved experimentally that the volitional stimulus, which regulates the various movements of the body, starts from definite portions of the brain according to the different results to be produced. This localisation of brain functions, though still far from being thoroughly understood, comes very appropriately into use in this inquiry. From it we learn that the homology which characterises the structural elements of the bodies of animals extends also to the component parts of their respective brains. The law which differentiates animals according to the greater specialisation of the functions of their various organs has therefore its counterpart in the brain, and we naturally expect an increase of brain substance in every case in which the functional activity of a specific organ is extended. Thus the act of stitching with a needle and thread, an act beyond the mental and physical capacity of any animal but man, would entail a certain increase of brain substance, simply in obedience to the great complexity of the movements involved in its execution, over and above that which may be supposed to be due to the intellectual and reasoning faculties which invented it.

That man's brain and his intelligence are correlated to each other is a fact too axiomatic to require any demonstration; nor can it be doubted that the relationship between them is of the nature of cause and effect. But to maintain that the amount of the latter is directly proportional to the size of the former is rather straining the laws of legitimate inference. In drawing any general conclusion of this nature from the bulk of brain substance, there are some modifying influences which cannot be disregarded, such, for example, as the amount of cranial circulation and the quality of the brain cells. But the determination of this point is not the exact problem with which the evolutionist is primarily concerned. To him the real crux in the inquiry is to account for the evolution of man's comparatively large brain under the influence of existing cosmic forces. After duly considering this problem, and casting about for a possible explanation, I have come to the conclusion that not only is it the result of natural laws, but that one of the main factors in its production was the conversion of the upper limbs into true hands. From the first moment that man recognised the advantage of using a club or a stone in attacking his prey or defending himself from his enemies, the direct incentives to a higher brain development came into existence. He would soon learn by experience that a particular form of club or stone was more suitable for his purposes; and if the desiderated object were not to be found among the natural materials around him, he would proceed to manufacture it. Certain kinds of stones would be readily recognised as better adapted for cutting purposes than others, and he would select his materials accordingly. If these were to be found only in a special locality, he would visit that locality whenever the prized material was needed. Nor would it be an unwarrantable stretch of imagination to suppose that the circumstances would lead him to lay up a store for future use. These simple acts of intelligence assume little more than may be seen in the actions of many of the lower animals. Consciousness of his power to make and to wield a weapon was a new departure in the career of man, and every repetition of such acts became an effective and ever-accumulating training force. What a memorable event in the history of humanity was the manufacture of the first sharp stone implement! Our sapient ancestor, who first used a spear tipped with a sharp flint, became possessed of an irresistible power over his fellow men. The invention of the bow and arrow may be parallelled with the discovery of gunpowder and the use of cannon, both of which revolutionised the principles of warfare in their respective ages. The art of making fire had a greater influence on human civilisation than the modern discovery of electricity. The first boat was in all probability a log—an idea which might have been suggested by the sight of an animal clinging to a floating piece of wood carried away by a flood. To scoop this log into a hollow boat was an afterthought. The successive increments of knowledge by which a single-tree canoe has been transformed into a first-class Atlantic liner are scattered through the unwritten and written annals of many ages. In his expeditions for hunting, fishing, fruit-gathering, &c., primitive man's acquaintance

with the mechanical powers of nature would be gradually extended, and *pari passu* with the increasing range of his knowledge there would be a corresponding development in his reasoning faculties. Natural phenomena suggested reflections as to their causes and effects, and so by degrees they were brought into the category of law and order. Particular sounds would be used to represent specific objects, and these would become the first rudiments of language. Thus each generalisation when added to his previous little stock of knowledge widened the basis of his intellectual powers, and as the process progressed man would acquire some notion of the abstract ideas of space, time, motion, force, number, &c.; and continuous thought and reasoning would ultimately become habitual to him. All these mental operations could only take place through the medium of additional nerve cells, and hence the brain gradually became more bulky and more complex in its structure. Thus the functions of the hand and of the brain have been correlated in a most remarkable manner. Whether the mechanical skill of the hand preceded the greater intelligence of the brain, or *vice versa*, I will not pretend to say. But between the two there must have been a constant interchange of gifts. According to Sir C. Bell, 'the hand supplies all instruments, and by its correspondence with the intellect gives him universal dominion.'[1]

That mind, in its higher psychical manifestations, has sometimes been looked upon as a spiritual essence which can exist separately from its material basis need not be wondered at when we consider how the pleasing abstractions of the poet, or the fascinating creations of the novelist, roll out, as it were, from a hidden cavern without the slightest symptom of physical action. It is this marvellous power of gathering and combining ideas, previously derived through the ordinary senses, which gives a *primâ facie* appearance of having here to deal with a force exterior to the brain itself. But indeed it is questionable if such psychological phenomena are really represented by special organic equivalents. May they not be due rather to the power of volitional reflection which summons them from the materials stored up by the various localised portions into which the brain is divided? From this point of view there may be many phases of pure cerebration which, though not the result of direct natural selection, have nevertheless as natural and physical an origin as conscious sensation. Hence imagination, conception, idealisation, the moral faculties, &c., may be compared to parasites which live at the expense of their neighbours. After all the greatest mystery of life lies in the simple acts of conscious sensation, and not in the higher mental combinations into which they enter. The highest products of intellectuality are nothing more than the transformation of previously existing energy, and it is the power to utilise it that alone finds its special organic equivalent in the brain.

But this brings us on controversial ground of the highest importance. Professor Huxley thus expresses his views on the phase of the argument now at issue:—

'I have endeavoured to show that no absolute structural line of demarcation, wider than that between the animals which immediately succeed us in the scale, can be drawn between the animal world and ourselves; and I may add the expression of my belief that the attempt to draw a psychical distinction is equally futile, and that even the highest faculties of feeling and of intellect begin to germinate in lower forms of life.'[2]

On the other hand, Mr. Alfred R. Wallace, who holds such a distinguished position in this special field of research, has promulgated a most remarkable theory. This careful investigator, an original discoverer of the laws of natural selection, and a powerful advocate of their adequacy to bring about the evolution of the entire organic world, even including man up to a certain stage, believes that the cosmic forces are insufficient to account for the development of man in his civilised capacity. 'Natural selection,' he writes, 'could only have endowed savage man with a brain a few degrees superior to that of an ape, whereas he actually possesses one very little inferior to that of a philosopher.' This deficiency in the organic

[1] *The Hand, &c. Bridgewater Treatise*, p. 38.
[2] *Evidences as to Man's Place in Nature*, p. 109.

forces of nature he essays to supply by calling in the guiding influence of a 'superior intelligence.' In defending this hypothesis from hostile criticism he explains that by 'superior intelligence' he means some intelligence higher than the 'modern cultivated mind,' something intermediate between it and Deity. But as this is a pure supposition, unsupported by any evidence, and merely a matter of personal belief, it is unnecessary to discuss it further. I would just, *en passant,* ask Mr. Wallace why he dispenses with this 'higher intelligence' in the early stages of man's evolution, and finds its assistance only requisite to give the final touches to humanity.

In dealing with the detailed objections raised by Mr. Wallace against the theory of natural selection as applied to man, we are, however, strictly within the sphere of legitimate argument; and evolutionists are fairly called upon to meet them. As his own theory is founded on the supposed failure of natural selection to explain certain specified peculiarities in the life of man, it is clear that if these difficulties can be removed, *cadit quæstio.* It is only one of his objections, however, that comes within the scope of my present inquiry, viz., that which is founded on the supposed 'surplusage' of brain power in savage and prehistoric races.

In comparing the brains of the anthropoid apes and man Mr. Wallace adopts the following numbers to represent their proportional average capacities, viz., anthropoid apes 10, savages 26, and civilised man 32—numbers to which there can be no objection, as they are based on data sufficiently accurate for the requirements of this discussion. In commenting on the mental ability displayed in actual life by the recipients of these various brains he states that savage man has 'in an undeveloped state faculties which he never requires to use,' and that his brain is much beyond his actual requirements in daily life. He concludes his argument thus:—'We see, then, that whether we compare the savage with the higher developments of man, or with the brutes around him, we are alike driven to the conclusion that in his large and well-developed brain he possesses an organ quite disproportionate to his actual requirements—an organ that seems prepared in advance, only to be fully utilised as he progresses in civilisation. A brain one half larger than that of the gorilla would, according to the evidence before us, fully have sufficed for the limited mental development of the savage; and we must therefore admit that the large brain he actually possesses could never have been solely developed by any of those laws of evolution whose essence is that they lead to a degree of organisation exactly proportionate to the wants of each species, never beyond those wants; that no preparation can be made for the future development of the race; that one part of the body can never increase in size or complexity, except in strict co-ordination to the pressing wants of the whole. The brain of prehistoric and of savage man seems to me to prove the existence of some power distinct from that which has guided the development of the lower animals through their ever-varying forms of being.'[1]

With regard to the closing sentence of the above quotation, let me observe that the cosmic forces, under which the lower animals have been produced by means of natural selection, do not disclose, either in their individual or collective capacity, any guiding power in the sense of a sentient influence, and I believe that the 'distinct power' which the author summons to his aid, apparently from the 'vasty deep,' to account for the higher development of humanity is nothing more than the gradually acquired product of the reasoning faculties themselves. Not that, for this reason, it is to be reckoned less genuine and less powerful in its operations than if it had emanated from an outside source. The reasoning power displayed by man is virtually a higher intelligence, and, ever since its appearance on the field of organic life, it has, to a certain extent, superseded the laws of natural selection. Physical science has made us acquainted with the fact that two or three simple bodies will sometimes combine chemically so as to produce a new substance, having properties totally different from those of either constituents in a state of disunion. Something analogous to this has taken place in the development of man's capacity for reasoning by induction. Its primary elements, which are

[1] *Natural Selection, &c.*, 1891, p. 193.

also those of natural selection, are conscious sensation, heredity, and a few other properties of organic matter ; elements which are common, in a more or less degree, to all living things. As soon as the sequence of natural phenomena attracted the attention of man, and his intelligence reached the stage of consecutive reasoning on the invariableness of certain effects from given causes, this new power came into existence; and its operations are, apparently, so different from those of its component elements that they can hardly be recognised as the offspring of natural forces at all. Its application to the adjustment of his physical environments has ever since been one of the most powerful factors, not only in the development of humanity, but in altering the conditions and life-functions of many members of the animal and vegetable kingdoms.

I have already pointed out that the brain can no longer be regarded as a single organ, but rather as a series of organs connected by bonds of union—like so many departments in a Government office in telephonic communication—all, however, performing special and separate functions. When, therefore, we attempt to compare the brain capacity of one animal with that of another, with the view of ascertaining the quality of their respective mental manifestations, we must first determine what are the exact homologous parts that are comparable. To draw any such inference from a comparison of two brains, by simply weighing or measuring the whole mass of each, would be manifestly of no scientific value. For example, in the brain of a savage the portion representing highly skilled motor energies might be very much larger, while the portion representing logical power might be smaller, than the corresponding parts in the brain of a philosopher. But should these inequalities of development be such as to balance each other, the weight of the two organs would be equal. In this case what could be the value of any inference as to the character of their mental endowments? Equal-sized brains do not display equivalent, nor indeed analogous, results. To postulate such a doctrine would be as irrational as to maintain that the walking capacities of different persons are directly proportional to the weight of their bodies. Similar remarks are equally applicable to the skulls of prehistoric races, as it would appear that evolution had done the major part of its work in brain development long before the days of neolithic civilisation. Huxley's well-known description of the Engis skull—'a fair average skull, which might have belonged to a philosopher, or might have contained the thoughtless brains of a savage'—goes far to settle the question from its anatomical point of view. Until localisation of brain functions makes greater progress it is, therefore, futile to speculate to any great extent on the relative sizes of the skulls of different races either in present or prehistoric times.

But there is another aspect of the question which militates against Mr. Wallace's hypothesis, viz., the probability that many of the present tribes of savages are, in point of civilisation, in a more degenerate condition than their forefathers who acquired originally higher mental qualities under natural selection. There must surely be some foundation of truth in the widely-spread tradition of the fall of man. And, if such be the case, we naturally expect to find some stray races with inherited brains of greater capacity than their needs, in more degenerate circumstances, may require. An exact equivalent to this may be seen in the feeble intellectuality of many of the peasants and lower classes among the civilised nations of modern times. Yet a youth born of such parents, if educated, often becomes a distinguished philosopher. It is well known that if an organ ceases to perform its functional work it has a tendency to deteriorate, and ultimately to disappear altogether. But from experience we know that it takes a long time for the effects of disuse to become manifest. It is this persistency that accounts for a number of rudimentary organs, still to be met with in the human body, whose functional activity could only have been exercised ages before man became differentiated from the lower animals. Such facts give some support to the suggestion, previously made, that philosophy, as such, has no specially localised portion in the brain. Its function is merely to direct the current of mental forces already existing.

But, again, Mr. Wallace's argument involves the assumption that the un-

necessarily large brain of the savage had been constructed on teleological principles for the sole purpose of philosophising. My opinion is that the greater portion of this so-called surplusage is the organic representative of the energy expended in the exercise of the enormous complexity of human actions, as displayed in the movements of his body and in the skilful manipulations necessary to the manufacture of implements, weapons, clothing, &c. All such actions have to be represented by a larger bulk of brain matter than is required for the most profound philosophical speculations. The kind of intelligence evinced by savages, however low their position in the scale of civilisation may be, is different from, and incomparably greater than, that manifested by the most advanced of the lower animals. To me it is much more rational to suppose that the development of the large brain of man corresponded, *pari passu*, with that of his characteristic physical attributes, more especially those consequent on the attainment of the upright position. That these attributes were acquired exclusively through the instrumentality of the cosmic forces was, as the following quotation will show, the opinion of Mr. Darwin:—'We must remember that nearly all the other and more important differences between man and quadrumana are manifestly adaptive in their nature, and relate chiefly to the erect position of man; such as the structure of his hand, foot, and pelvis, the curvature of his spine, and the position of his head.'[1] Mr. Wallace, however, considers the feet and hands of man 'as difficulties on the theory of natural selection.' 'How,' he exclaims, 'can we conceive that early man, *as an animal*, gained anything by purely erect locomotion? Again, the hand of man contains latent capacities and powers which are unused by savages, and must have been even less used by palæolithic man and his still ruder predecessors. It has all the appearance of an organ prepared for the use of civilised man, and one which was required to render civilisation possible.'[2] But here, again, this acute observer diverges into his favourite by-path, and introduces a 'higher intelligence' to bridge over his difficulties.

We have now reached a stage in this inquiry when a number of questions of a more or less speculative character fall to be considered. On the supposition that, at the start, the evolution of the hand of man was synchronous with the higher development of his reasoning faculties, it is but natural to ask where, when, and in what precise circumstances this remarkable coalition took place. I would not, however, be justified in taking up your time now in discussing these questions in detail; not because I think the materials for their solution are unattainable, but because, in the present state of our knowledge, they are too conjectural to be of scientific value. In the dim retrospective vista which veils these materials from our cognisance I can only see a few faint landmarks. All the osseous remains of man which have hitherto been collected and examined point to the fact that, during the larger portion of the Quaternary period, if not, indeed, from its very commencement, he had already acquired his human characteristics. This generalisation at once throws us back to the Tertiary period in our search for man's early appearance in Europe. Another fact—disclosed by an analysis of his present corporeal structure—is that, during a certain phase of his previous existence, he passed through a stage when his limbs, like those of the present anthropoid apes, were adapted for an arboreal life. We have therefore to look for the causes which brought about the separation of man from his quadrumanous congeners, and entailed on him such a transformation in his form and habits, in the physical conditions that would supervene on a change from a warm to a cold climate. In the gradual lowering of the temperature of the subtropical climate which prevailed in Central Europe and the corresponding parts of Asia during the Miocene and Pliocene periods, and which culminated in the great Ice age, together with the concurrent changes in the distribution of land, seas, and mountains, we have the most probable explanation of these causes. Whether man forsook his arboreal habits and took to the plains from overcrowding of his own species in search of different kinds of food, before this cold period subjected him to its intensely adverse circumstances, it would be idle for me to offer an opinion. Equally conjectural

[1] *Descent of Man*, p. 149. [2] *Natural Selection*, p. 198.

would it be to inquire into the exact circumstances which led him to depend exclusively on his posterior limbs for locomotion.

During this early and transitional period in man's career there was no room for ethics. Might was right, whether it emanated from the strength of the arm, the skill of the hand, or the cunning of the brain. Life and death combats would decide the fate of many competing races. The weak would succumb to the strong, and ultimately there would survive only such as could hold their own by flight, strength, agility, or skill, just as we find among the races of man at the present day.

In summing up these somewhat discursive observations, let me just emphasise the main points of the argument. With the attainment of the erect position, and the consequent specialisation of his limbs into hands and feet, man entered on a new phase of existence. With the advantage of manipulative organs and a progressive brain he became *Homo sapiens*, and gradually developed a capacity to understand and utilise the forces of nature. As a handicraftsman he fashioned tools and weapons, with the skilful use of which he got the mastery over all other animals. With a knowledge of the uses of fire, the art of cooking his food, and the power of fabricating materials for clothing his body, he accommodated himself to the vicissitudes of climate, and so greatly extended his habitable area on the globe. As ages rolled on he accumulated more and more of the secrets of nature, and every such addition widened the basis for further discoveries. Thus commenced the grandest revolution the organic world has ever undergone—a revolution which culminated in the transformation of a brute into civilised man. During this long transitional period mankind encountered many difficulties, perhaps the most formidable being due to the internecine struggles of inimical members of their own species. In these circumstances the cosmic processes, formerly all-powerful so long as they acted only through the constitution of the individual, were of less potency than the acquired ingenuity and aptitude of man himself. Hence local combinations for the protection of common interests became necessary, and with the rise of social organisations the safety of the individual became merged in that of the community. The recognition of the principle of the division of labour laid the foundations of subsequent nationalities, arts, and sciences. Coincident with the rise of such institutions sprang up the germs of order, law, and ethics. The progress of humanity on these novel lines was slow, but in the main steadily upwards. No doubt the advanced centres of the various civilisations would oscillate, as they still do, from one region to another, according as some new discovery gave a preponderance of skill to one race over its opponents. Thus the civilised world of modern times came to be fashioned, the outcome of which has been the creation of a special code of social and moral laws for the protection and guidance of humanity. Obedience to its behests is virtue, and this, to use the recent words of a profound thinker, 'involves a course of conduct which, in all respects, is opposed to that which leads to success in the cosmic struggle for existence. In place of ruthless self-assertion it demands self-restraint; in place of thrusting aside or treading down all competitors, it requires that the individual shall not merely respect but shall help his fellows; its influence is directed, not so much to the survival of the fittest, as to the fitting of as many as possible to survive. It repudiates the gladiatorial theory of existence. It demands that each man who enters into the enjoyment of the advantages of a polity shall be mindful of his debt to those who have laboriously constructed it; and shall take heed that no act of his weakens the fabric in which he has been permitted to live. Laws and moral precepts are directed to the end of curbing the cosmic process and reminding the individual of his duty to the community, to the protection and influence of which he owes, if not existence itself, at least the life of something better than a brutal savage.'[1]

These humble remarks will convey to your minds some idea of the scientific interest and profound human sympathies evoked by the far-reaching problems which fall to be discussed in this Section. Contrasting the present state of anthropological science with its position some thirty or forty years ago, we can only marvel

[1] Huxley, on *Evolution and Ethics*, p. 33.

at the thoroughness of the change that has taken place in favour of its doctrines. Now man's immense antiquity is accepted by a vast majority of the most thoughtful men, and his place in nature, as a derivative animal at the head of the great chain of life, appeals for elucidation to all sciences and to all legitimate methods of research. But among the joyful pæans of this triumphal march we still hear some discordant notes—notes, however, which seem to me to die with their echoes, and to have as little effect on scientific progress as the whistling of an idle wind. For my own part I cannot believe that a science which seeks in the spirit of truth to trace the mysteries of human life and civilisation to their primary rootlets, a science which aims at purging our beliefs of superstitious figments generated in days when scientific methods were too feeble to expose the errors on which they were founded, a science which reminds us in a thousand ways that success in life depends on a correct knowledge of the cosmic forces around us, can be opposed to the highest and most durable interests of humanity.

The following Papers and Reports were read:—

1. *On the Ethnographic Aspect of Dancing.* *By* Mrs. Lilly Grove, *F.R.G.S.*

Dancing corresponds to a universal primitive instinct in man. The value of a scientific study of dancing as illustrating some aspects of ethnology is very great. At all periods there were three kinds of dances:—1. The *imaginative* or poetic. 2. The *descriptive.* 3. The *religious.* This last is most important, and may be called the fountain of the other kinds. Dancing is connected with every ancient myth. Among the savages the idea of magic always accompanies it. Religious dances can be divided in (*a*) *dances directly in honour of the Deity;* (*b*) *dances on various occasions intended to propitiate the Deity.* A strange feature is the fact that so many dances are performed in a circle. *Sun-dances* are numerous. *War-dances* are of two orders, either as a *preparation for war* or as a *rejoicing after triumph.* The Corrobberree illustrates the former aspect. Excellence in dancing among savages is obtained by very simple means; anyone who makes a mistake in the dance is killed.

Women take a larger share in the dance than men. This is accounted for by Herbert Spencer.

Marriage-dances are found in every tribe. So are *devil-dances,* used as exorcisms or as a medicine cure. The dance of the Veddahs of Ceylon, the Baile de Pifano of Chili, the skeleton-dance of Australia, belong to this class. Dancing in the cathedrals of Spain and Mexico is traced back to a Hebrew custom, and to King David's act of adoration. Dancing may be the outcome of pain and sorrow as well as the expression of joy. Funeral dances are common in Nubia and Central America, and were much in favour with the ancient Egyptians. In conclusion, the universality and the naturalness of dancing make it an important factor in the history of man.

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2. *Report on the Anthropometric Laboratory.*—See Reports, p. 654.

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3. *Report on the Physical Deviations from the Normal among Children in Elementary and other Schools.*—See Reports, p. 614.

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4. *On Anthropometric Work in Large Schools.* *By* Bertram C. A. Windle, *D.Sc., M.D., M.A.*

This paper gives the results obtained in answer to a circular sent to the head masters of one hundred of the largest schools in England, Scotland, and Ireland inquiring whether any, and if so what, anthropometric investigations were carried on in their institutions, and the methods adopted in taking the various measure-

ments. The replies show that some form of measurement is, or has been, carried on in twenty-five schools, details of which will be found in the table below (Table 1). They also show that the methods adopted differ considerably (Table 2), a fact which somewhat detracts from the value of the observations for comparative purposes.

The advantages of systematic measurements of boys from the scholastic and the scientific points of view are alluded to, and it is suggested that an endeavour should be made to encourage and systematise such work in large schools.

TABLE 1.—*Measurements Taken* (Number of Schools, 25).

Height	25	Length of arm	3	Sight	5
Weight	21	Girth ,,	10	Colour-blindness	1
Chest-girth	23	Length of forearm	3	Hearing	1
Size of head	0	Girth ,,	10	Lift, or Archer's pull	2

TABLE 2.—*Methods of Taking Measurements.*

HEIGHT.		WEIGHT.		CHEST GIRTH.	
In boots	1	In ordinary clothes	2	In ordinary clothes	0
In gymnastic shoes	3	In gymnastic ,,	15	In gymnastic ,,	7
In socks	15	Naked	0	Naked	12
In bare feet	1	Not mentioned	4	Not mentioned	4
Not mentioned	5				

5. *Notes on Anthropometric Weighing.* *By* W. WILBERFORCE SMITH, *M.D., M.R.C.P.*

Some 25,000 separate weighings, made by the author in the course of years, afford some results interesting to the Section, notwithstanding that others, forming the greater part of his observations, are outside its scope. Thus, in June 1892, twelve men of the Horse Guards were tested. Apart from the bodyweight, together with height, breathing capacity, &c., of these fine fellows, it is suggestive to notice the immense weight of the accoutrements which they wear as ordinarily seen in public. The charts shown also illustrated the following points, viz., the relation of weight to chest-girth, the regular growth of girls, and the remarkable increase which occurs at the time of emergence into womanhood, rapid loss of nutrition associated with departure from home routine, weight in corpulency, and the effect of alcohol and of its cessation.

FRIDAY, SEPTEMBER 15.

The following Report and Papers were read:—

1. *Report on the Ethnographical Survey of the United Kingdom.*

See Reports, p. 621.

2. *On Anglo-Saxon Remains and Coeval Relics from Scandinavia.* *By* Professor HANS HILDEBRAND.

3. *On the Origin and Development of Early Christian Art in Great Britain and Ireland.* *By* J. ROMILLY ALLEN, *F.S.A.Scot.*

The object of this paper is to trace the various decorative elements found in early Christian art in Great Britain to their source, and to show in what way the native styles of art existing in this country at the time of the introduction of

Christianity (*circa* A.D. 450) were influenced, first by the Italo-Byzantine art, which came in with the importation of the illuminated MSS. used in the service of the Church, and subsequently by the coming in contact of the Anglo-Saxon and Scandinavian conquering races with the Celtic and other populations already inhabiting the British Isles. Early Christian art in this country is essentially decorative, and to a lesser extent symbolic. The conventional grouping and general treatment of the figure-subjects show that they are obviously barbarous copies of Byzantine originals. If any definite conclusions are to be arrived at with regard to the evolution of early Christian art in Great Britain, it must be by a careful examination and comparison of the minute details of the ornament. The ornament consists of the following elements:—

(1) Interlaced work (2) Key patterns (3) Step patterns (4) Spirals	} Geometrical.
(5) Zoömorphic designs (6) Anthropomorphic designs (7) Phyllomorphic designs	} Suggested by animal, human, and vegetable forms.

The possible sources whence each of these different patterns was derived are next to be considered. These are divided into the native or imported styles of decorative art existing in Great Britain previous to the introduction of Christianity—namely, the art of the ages of stone, bronze, and iron, and Romano-British art; and the external sources, made accessible after A.D. 450—namely, the Italo-Byzantine, Anglo-Saxon, and Scandinavian styles. The spirals are to be traced to a 'late Celtic' source in the late iron age, the interlaced work and phyllomorphic designs to an Italo-Byzantine source, the step patterns possibly to a Saxon source, the zoömorphic designs perhaps to a Scandinavian source, and the key patterns to the classical fret adapted to suit the diagonal setting-out lines usually employed in drawing early Christian ornament in Great Britain.

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4. *On an Implement of Hafted Bone, with a Hippopotamus Tooth inserted, from Calf Hole, near Grassington. By* Rev. E. JONES.

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6. *The Prehistoric Evolution of Theories of Punishment, Revenge, and Atonement. By* Rev. G. HARTWELL JONES.

Even the brilliant civilisation of *Kulturvölker* retains traces of a primitive barbarism. While the investigations of Waitz, Tylor, Lubbock, &c., into the life of *Naturvölker* are instructive in showing the growth of thought, the origin of institutions must be looked for among 'Aryans.' Wherever they come from, or, more correctly speaking, whenever the phase of civilisation associated with the name Aryan came into existence, their high capacity for development was evoked or stimulated by contact with Semitic or Hamitic races.

A further attempt is made here, by the aid of (i.) philology, (ii.) archæology in its widest sense, to bridge the gulf between the rude notions of the *Urvolk* and distinct developments in Southern Europe.

The features considered here are found, not only among *Kulturvölker*, but also among unprogressive races from the Antipodes to Archangel. Yet, not only are there differences between 'Aryan' and Semitic conceptions, but even deviations among branches of the same family of races.

Though it has been maintained, on the high authority of Ottfried Müller and Philippi, that the Greek legal systems originated independently, Leist, no doubt rightly, traces them to a common inheritance.

The richness of the sources varies with the mental endowments, the intellectual activity, and the literary monuments of the several races.

The question of punishment, &c., had its (1) religious, (2) secular aspect.

As among many rude races in modern times there is no system of public

punishment, so there the act of retaliation devolved upon the individual injured. Still, it is not entirely a private matter, for it is part of the system of centralisation: in the first degree under the head of the family, in the second under the sacerdotal classes, the chieftain, prince, or king, or both together.

Though the phases overlap we may distinguish (I.) *punishment by the individual;* (II.) *punishment by the community or its representative.*

I.

Punishment by the individual.—The custom is widespread and far older than 'Aryans,' and the reason for it is evident—because the organisation of society is too loose.

The first points considered were, Who took the initiative, and was the act intentional?

Offences calling for retribution.—The Greek conception of ὕβρις and ἄρχειν χειρῶν ἀδίκων.

(i.) *Injury,* including such offences as adultery and incest, which were visited with the severest penalties.

(ii.) *Theft:* its recognition attested by the antiquity of such words as *clepere* = κλέπος.

(iii.) *Assault,* not confined to the plaintiff's person.

Murder: its far-reaching consequences. Murder by (i.) weapon; (ii.) burning; (iii.) poison. Murder (a) culpable; (β) pardonable; (γ) justifiable; (δ) premeditated.

These offences might be *manifest,* in which case they were avenged on the spot; or *non-manifest,* in which case examination was necessary.

Methods of procedure.—The superstition of μασχαλίζειν; the imprecation; the avenging fiend. (A) Punishment by the spirit of the murdered.

(B) Punishment by relatives. First phase: passion for revenge; linguistic evidence.

Second phase: execution; guilt falls upon the head; the vendetta; *talio; asyla;* banishment.

Third phase: reparation by fine; linguistic evidence. (a) Fines paid to person or relatives according to the member maimed or the rank of the injured. Anglo-Saxon, *wergeld;* Old Welsh, *galanas;* ποινή; *pœna.* (β) Restitution to the community; ἐπιβολή; Lat. *multa;* and Old Welsh, *sarhaad.*

Parricide: its heinous and unnatural character; the sack punishment; imperilled family succession and worship; at first unpardonable, later expiable.

The ideas of purification, &c., elaborated in the Indian *Prayaçcitta.*

II.

Punishment by the community or representatives hardly falls within the scope of this inquiry, being of later growth.

Though found in rudimentary forms at an early period, society did not directly interfere, except to regulate punishment. The *authorities* by whom it was exercised: (i.) the head of the family, *patria potestas;* the priest; the king; Sanskrit *daṇḍa;* (ii.) tribunals: Areopagus; Ephetæ; Curia.

Punishment in the next world.—The growth of these ideas, of revenge, punishment, and atonement, mirrored in Homer, where poems, as, *e.g.,* 'Iliad,' xviii. 497–508, if microscopically examined, reveal the successive stages of growth.

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7. *'Four' as a Sacred Number. By* Miss A. W. Buckland.

Miss Buckland, in following out the subject of a former paper read before the Anthropological Section, entitled 'Points of Contact between Old-world Myths and Customs and the Navajo Myth entitled "The Mountain Chant,"' finds so many allusions to 'four' as a sacred number, and its connection with the cardinal points, and to the cross as a symbol of these points, or of the winds blowing from

them, that she has thought it desirable to place on record the numerous cases in which this symbolism is in accord with the ancient Central American sculptures and the Mexican picture-writings; also to trace the same symbolism in the Old World, believing that through it may be found a key to many migrations, and to much of the intercourse between the Old World and the New in prehistoric times.

SATURDAY, SEPTEMBER 16.

The following Papers were read:—

1. *On Ancient Metal Implements from Egypt and Lachish.* *By* Dr. J. H. GLADSTONE.—See p. 715.

2. *Notes on Flint Saws and Sickles.* *By* ROBERT MUNRO, *M.D.*

The announcement a few years ago of the discovery, by Dr. Flinders Petrie, of corn sickles made of wooden casings, having as teeth a number of serrated flint flakes inserted along a groove in the concave edge of the implement, and the almost simultaneous publication by Dr. Munro of the discovery of double-handed saws similarly constructed in the Polada lake-dwelling in Italy, have led to a speculative discussion[1] as to whether or not the so-called flint saws, so abundantly found among the prehistoric remains of all countries in Europe, might not have been the eliminated teeth of such saws or sickles. The author of this paper sees in this discussion an occasion for reviewing the materials in Western Europe bearing on the problem thus raised. In the abundance of flint saws during the Stone Age in Europe, contrasted with the rarity of this implement when made of bronze in the succeeding age, he recognised a *primâ facie* argument in favour of the existence of such compound sickles. The result of his investigation into the matter is thus stated: 'In conclusion, we must not forget that our primary basis of facts rests on the productions of two widely distant archæological areas, which must therefore be treated separately and independently of each other. The discovery of these very interesting Egyptian sickles can, at best, be only used as a hypothetical suggestion of the existence of analogous implements elsewhere. In support of the theory that such sickles were in use among the prehistoric people of Western Europe, the author finds in this rapid review of existing materials little or no evidence. On the other hand, the compound Polada saws are equally suggestive of a wider application, and we may, with greater probability of success, look out for the remains of similar implements among the *débris* of prehistoric civilisations beyond that of the lake-dwellings of Europe.'

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3. *On Prehistoric Remains in Crete.* *By* JOHN L. MYRES.

The objects described were obtained from a cave in the valley above Kamárais, on the south side of the mountain mass of Psiláríti (Mount Ida) in Crete. They consist wholly of fragments of pottery, of shapes which resemble somewhat those of the pre-Mykenæan pottery from Santorin, Syra, and Amorgòs, but decorated with fine black glaze, and, above this, with geometrical and floral patterns in white, yellow, and two shades of red. On one fragment part of a human figure is represented, in a style which recalls that of some Mykenæan examples. Some points of likeness have been noticed between these specimens and those found by Professor Flinders Petrie at Kahun, and attributed by him to the period of the twelfth Egyptian dynasty. But until a further examination has been made of the Kamárais cave it is impossible to date the new find with any certainty.

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[1] *Archæological Journal,* vol. xlix. pp. 53, 164.

4. *Funeral Rites and Ceremonies among the Tshinyaï, or Tshinyangwe.* *By* LIONEL DECLE.

5. *The Arungo and Marombo Ceremonies among the Tshinyangwe.* *By* LIONEL DECLE.

6. *The Ma-Goa.* *By* LIONEL DECLE.

MONDAY, SEPTEMBER 18.

The following Report and Papers were read:—

1. *Report on the Exploration of Ancient Remains in Abyssinia.*

See Reports, p. 557.

2. *On the External Characters of the Abyssinians examined by Mr. Bent.* *By* J. G. GARSON, *M.D.*—See Reports, p. 563.

3. *Ethnographical Notes relating to the Congo Tribes.* *By* HERBERT WARD, *F.R.G.S.*

The subjects that are treated at greatest length in this paper relate to superstition and general customs. In the description of the 'N'Kimba' ceremony of the Lower Congo natives we learn, for the first time, the motive for this remarkable 'secret society.' Native eloquence is a subject containing interesting information; but the most important subjects are those which bear briefly upon women, their condition and circumstances. The method of cicatrisation, which is a universal practice among the tribes of the Upper Congo, is described; and much concise information is given concerning the adornment and decoration of the Congo natives in that portion of the paper devoted to costume.

4. *On the Mad Head.* *By* CROCKLEY CLAPHAM, *M.D.*

The author stated that the older phrenology of Gall had been superseded by Ferrier's cerebral localisation. He then gave some results of his examination of nearly 4,000 insane heads. For statistics and particulars he referred to papers by him ('Brain Weights and Head Measurements of Insane') in Hack-Tuke's 'Psychological Dictionary.' His observations were drawn from eight asylums in the north of England and south of Scotland, and these compared with a number of sane heads.

Insane heads he found to show a larger average size than sane ones, though insane brains were smaller. His standard of comparison was by a *cranial index*, which he obtains by adding together the measurements of the whole circumference and the antero-posterior and transverse arches of the head. Of these measurements that of the transverse arch was the only one smaller in the insane, and was in fact the weak point in the insane. The cranial index he found further useful, as when expressed in inches it indicated nearly the weight of the normal contained brain in ounces.

Female heads were smaller and more symmetrical than male.

Heads increased in size with increased body height and weight; heads of those over forty years of age larger than those under forty; larger in dark- than in fair-complexioned individuals; larger in insane professional men than in

other classes of insane, and also larger than in *sane* professional men. Gardeners had the smallest heads. Bricklayers' heads were larger than cabinetmakers'. A table was shown illustrating the fact that heads enlarged as you went north, but not regularly, as the smallest heads were from Perthshire.

The frontal segment of head circumference bore a *larger* proportion to whole circumference in insane, which, with the fact of frontal lobes weighing more in proportion to whole encephalon in idiots and imbeciles than in total insane class, and the fact that the typical insane head was cuneiform with the greatest transverse diameter anterior to central point of head, seemed to discredit the 'noble forehead,' and point out the occipital lobes as the seat of intelligence. This was supported by facts of brain development and comparative cerebral anatomy, as well as by the flat occiput of idiots and the cerebellum of the Bushmen projecting beyond the occipital lobes.

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5. *On the Dards and Siah-Posh Kafirs.* *By* J. Beddoe, *M.D., F.R.S., and* Dr. Leitner.

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6. *Pin-wells and Rag-bushes.* *By* E. Sidney Hartland, *F.S.A.*

Professor Rhys has lately brought together a number of instances, in Wales and the Isle of Man, in which persons frequenting sacred wells for the cure of disease and other purposes have been in the habit of throwing pins into the water, stuffing rags under stones, or tying rags upon adjacent trees; and he has discussed the reasons for these practices, suggesting that the pins are offerings and the rags are vehicles for the transfer of the disease. The object of the present paper is to consider these and other suggestions. A few of the most characteristic observances at wells now or formerly held sacred in Wales are first brought together. They are compared with ancient and modern observances on the continent of Europe and elsewhere at sacred wells, crosses, trees, temples, and other objects of superstition. Professor Rhys' suggestions, and the theory recently put forward by M. Monseur in the 'Bulletin de Folklore' as to the observances at sacred crosses and trees, are then discussed. M. Gaidoz, ten years ago, in the 'Revue de l'Histoire des Religions,' dealing with the same class of cases as M. Monseur, expressed the opinion that pins and nails were merely substantial reminders for the deity whose aid was invoked. None of these solutions, however, fulfils all the conditions. A satisfactory solution must apply equally to the crosses and shrines as to the wells and trees, to the driving of nails as to the dropping of pins and the tying of rags. It is therefore suggested that the object of the usages was union with the divinity, to be achieved by the perpetual contact with the god of some article identified with the worshipper. It cannot, of course, be denied that the ideas of offerings and of transfer of disease have attached to some of the rites in later times; but it is submitted that the original intention was different, and that these explanations only arose after the real motive was forgotten.

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7. *On the Primitive Americans.* *By* Miss J. M. Welch.

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8. *On the Indians of the Mackenzie and Yukon Rivers, Canada.* *By* the Right Rev. Dr. Bompas, *Bishop of Selkirk.*

These Indians are of Mongolian race, and appear to have migrated from Asia. They are distinct from the Esquimaux and other circumpolar races. Their languages are agglutinative, and in some cases almost monosyllabic. They dress in skins, inhabit houses of skins stretched over wooden frames, and occupy themselves mainly with hunting. Their arrows are pointed with bone, flint, and more recently with iron, and hammer-headed arrows are used for striking small birds. In summer they live largely on the great rivers in canoes of pine trunks or birch bark; heavy

loads of meat are transported in large boats of moose-skin. They practise ivory and wood carving, produce fire by means of a drill, cook their food in water-tight wicker baskets, and formerly tattooed their persons with characteristic marks. The dead are exposed on platforms, out of reach of the wild beasts. European culture is fast obliterating the national peculiarities.

9. *On the Australian Natives.* *By* Miss J. A. FOWLER.

10. *On a Modification of the Australian Aboriginal Weapon termed the Leonile, Langeel, Bendi, or Buccan.* *By* R. ETHERIDGE, Jun.

11. *On an Unusual Form of Rush-basket from the Northern Territory of South Australia.* *By* R. ETHERIDGE, Jun.

TUESDAY, SEPTEMBER 19.

The following Papers and Reports were read:—

1. *Recent Introduction into the Indian Army of the Method of Finger Prints for the Identification of Recruits.* *By* FRANCIS GALTON, *F.R.S.*

Mr. Galton read copies of official letters just received by him from Surgeon Lieut.-Colonel Hendley, of Jeypore, who had memorialised the authorities in India in favour of affixing to the nominal roll of recruits an impression in ink of the fore, middle, and ring fingers of each recruit, offering at the same time to do so in respect to those whom he himself examined for fitness to serve. In reply the Commander-in-Chief 'approved of the proposal to employ prints of finger-tips as marks for identification, as they are so extremely easy to make, and so useful in guarding against personation.'

Surgeon Lieut.-Colonel Hendley has had considerable experience in taking such imprints, having already sent to Mr. Galton those of the ten digits of nearly 1,000 persons, most of whom were prisoners in the gaol of Jeypore.

2. *On the Excavation of the Stone Circle of Lag-ny-Boiragh on the Meayll Hill at Port Erin, Isle of Man.* *By* P. M. C. KERMODE, *F.S.A.Scot.*, *and* Professor W. A. HERDMAN, *F.R.S.*

This was found on excavation to be a circle of eighteen graves arranged in six sets of three. In each set two graves are tangentially placed, and the third is radial, projecting outwards from the circle. For such a triradiate arrangement the term 'tritaph' is proposed. The sides and ends of the tangential graves are usually formed of single large stones (up to ten feet in length), while the radial graves (?) have two pairs of smaller upright stones at their sides, and no end stones. Possibly they may have been built as passages, but remains of cinerary urns were found in them, as well as in the tangential graves. About two feet from the surface was the floor of the grave, composed of flat slabs of various sizes, and under these slabs we found the broken urns, charcoal, fragments of charred bone, black oily earth, several flint arrow-heads, scrapers, knives, &c. Near the floor of the grave was also found in every case a number of rounded white quartz stones, evidently brought up from the sea-shore.

A full account of the excavation will be published shortly in the 'Trans. Biol. Soc. Liverpool,' vol. viii.

3. *On the Structure of Lake Dwellings.* *By* Robert Munro, *M.D.*

In this communication Dr. Munro described the various methods adopted by the lake-dwellers in the construction of the under-structures and platforms on which their huts had been placed:—

(1) *Pfahlbauten,* or pile-structures proper.

(2) Solid basements of wood, or islands made of mixed materials, crannogs, fascine structures, &c.

(3) Cellular basements of beams arranged like a log-house.

After noticing the fragmentary indications of huts collected from time to time on the sites of lake-dwellings, the author went on to describe the ruins of a cottage exposed a few years ago by peat-cutters at the Schussenried, Würtemberg. It was of a rectangular shape, measuring thirty-three feet long by twenty-three feet broad, and its walls were constructed of wooden beams plastered over with clay. Its interior was divided into two compartments, one of which contained a hearth. Dr. Munro then gave a description of an equally important discovery recently made in Argyllshire. This was a crannog showing foundations of a circular house thirty-two feet in diameter, and also divided into two compartments, one of which contained a hearth and the remains of a doorway.

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4. *A British Village of Marsh Dwellings at Glastonbury.* *By* Arthur Bulleid, *F.S.A.*

This village, discovered by Mr. Arthur Bulleid in March 1892, is situated a little more than a mile north of the town of Glastonbury, in the upper part of one of the moorland levels of Central Somerset found to the south of the Mendip Hills. The site is fourteen miles from the coast of the Bristol Channel, but only about 15 feet above high-water level. As late as 1540 the neighbouring lands were occupied either by areas of water or swamp, one mere being five miles round. The village is bounded on its east side by a natural watercourse.

There is little on the surface to indicate the site of a village, but on careful inspection between sixty and seventy low circular mounds may be seen, varying from 15 to 35 feet in diameter, and from 6 inches to 2 ft. 6 in. high at the centre. These form the foundations or floors of separate dwellings, which are constructed in the following way:—On the surface of the peat is a layer or platform of timber and brushwood kept in place by numerous small piles at the margin. On this a layer of clay is placed, slightly raised at the centre, where the remains of a hearth are generally found. The dwelling itself was composed of timber filled in with wattle and daub. Not only have the wall-posts been found *in situ*, but also the entrance threshold and doorstep.

The extent of the ground covered by the sixty or seventy mounds measures more than 400 feet north and south, by 300 feet east and west. The east border of the settlement has been met with, and is well defined by a thick line of piles and timber. This side of the village was undoubtedly, to begin with, protected by water, which in course of time was replaced by an accumulation of a peaty nature. It is in and on this formation outside the settlement that many interesting structures entering into the construction of the village have been unearthed, such as banks of clay and stone, morticed timber and hurdlework. Among other things that have been discovered is a boat 17 feet long, quantities of wheel and hand-made pottery, sling stones, and bones of animals, and a great number of objects of bronze and iron, horn, bone, and stone, such as fibulæ and rings, knives, saws and weapons, combs, needles, pottery stamps, and querns.

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5. *On the Place of the Lake Dwellings at Glastonbury in British Archæology.* *By* Professor W. Boyd Dawkins, *F.R.S.*

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6. *On Early Uses of Flint in Polishing.* *By* H. STOPES.

The author exhibited and described a quantity of flints that had attained a highly polished or grooved surface from having been used for polishing. Several of these had been elaborately shaped for use, and presented two or more smoothed or polished facets. They were ordinary nodules, tabular flint, echini, shells or shell-casts filled with flint and broken or worn to a fine surface, &c. Many of them have been polished neolithic axes, and have served as hammer stones and other purposes as well as polishers. A great number are small spear-heads and arrow-heads. In many cases they have been worn to a considerable degree. They come from numerous places, but chiefly the Thames Valley, Kent.

7. *On Palæolithic Anchors, Anvils, Hammers, and Drills.* *By* H. STOPES.

The author pointed out the great importance of ascertaining the history of the development of tools, as the increase of mental power was greatly secured by improved skill in the manufacture and use of tools. The action was (and is) reflex. The author defined tools as objects made and used intelligently for a specific purpose, not missiles or other things used naturally, although it is not yet possible to distinguish many of these objects. Many specimens of flint and other stones were exhibited that bore traces of having been made and used as anchors, net weights, sinkers, &c., that were trimmed, round holes occurring naturally in the stone. The use and fabrication of these, and also the wood and bone doubtless worked at the same time, led to the use of anvils, hammers, and drills, many of which were shown. Especial attention was drawn to one form of drill that, with a point and cutting edges, strongly resembles modern steel augurs or centre-bits. All these tools have been found at Northfleet, Kent, at the Milton Street pit, 100 feet above O.D., excepting a few older ones from the higher plateau of Kent. These possess the characteristic deep-red ferruginous tint, and are well worked and waterworn.

8. *Report on Uniformity in the Spelling of Barbaric and Savage Languages and Race-names.*—See Reports, p. 662.

9. *Interim Report on the North-Western Tribes of the Dominion of Canada.* See Reports, p. 653.

INDEX.

References to reports and papers printed in extenso *are given in Italics.*
*An Asterisk * indicates that the title only of the communication is given.*
The mark † indicates the same, but a reference is given to the Journal or Newspaper where the paper is published in extenso.

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Life Members (since 1845), and all Annual Members who have not intermitted their Subscription, receive gratis all Reports published after the date of their Membership. Any other volume they require may be obtained on application at the Office of the Association, Burlington House, Piccadilly, London, W., at the following prices, viz.—Reports for 1831 to 1874 (*of which more than* 15 *copies remain*), at 2*s*. 6*d*. per volume; after that date, at two-thirds of the Publication Price. A few sets, from 1831 to 1874 inclusive, may also be obtained at £10 per set.

Associates for the Meeting in 1893 may obtain the Volume for the Year at two-thirds of the Publication Price.

REPORT OF THE FIFTY-EIGHTH MEETING, at Bath, September 1888, *Published at* £1 4*s*.

CONTENTS:—Third Report of the Committee for promoting Tidal Observations in Canada;—Report of the Committee for considering the desirability of introducing a Uniform Nomenclature for the Fundamental Units of Mechanics, and of co-operating with other bodies engaged in similar work;—Fourth Report on the best means of Comparing and Reducing Magnetic Observations;—Fourth Report on Standards of Light;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Second Report on the Bibliography of Solution;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Second Report on the Influence of Silicon on the properties of Steel;—Third Report of the Committee for inviting designs for a good Differential Gravity Meter in supersession of the pendulum;—Report on the present methods of teaching Chemistry;—Report on the action of Light on the Hydracids of Halogens in presence of Oxygen;—Second Report on the Nature of Solution;—Report of the Committee for making arrangements for assisting the Marine Biological Association Laboratory at Plymouth;—Third Report on Isomeric Naphthalene Derivatives;—Third Report on the Prehistoric Race in the Greek Islands;—Report on the effects of different occupations and employments on the Physical Development of the Human Body;—Sixteenth Report

on the Erratic Blocks of England, Wales, and Ireland;—Report of the Committee for preparing a further Report upon the Provincial Museums of the United Kingdom; —Second Report on the 'Manure' Gravels of Wexford;—Report of the Committee for continuing the Researches on Food-Fishes at the St. Andrews Marine Laboratory; —Fourteenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Migration of Birds;—Report on the Flora of the Carboniferous Rocks of Lancashire and West Yorkshire;—Report on the Occupation of a Table at the Zoological Station at Naples;—Report on the teaching of Science in Elementary Schools;—Sixth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Second Report on the best method of ascertaining and measuring Variations in the Value of the Monetary Standard;—Report as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief forms in which the Money is employed, and the amount annually used in the Arts;—Fourth Report on the North-Western Tribes of the Dominion of Canada;—Report of the Corresponding Societies Committee;—Second Report on the Prehistoric Inhabitants of the British Islands;—Third Report of the Committee for drawing attention to the desirability of prosecuting further research in the Antarctic Regions;—Report of the Committee for aiding in the maintenance of the establishment of a Marine Biological Station at Granton, Scotland;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Report of the Committee to arrange an investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom, in co-operation with the local societies represented on the Association;—Report on an ancient Sea-beach near Bridlington Quay;—Report on the Development of the Oviduct and connected structures in certain fresh-water Teleostei;—Third Report on Electrolysis in its Physical and Chemical Bearings;—Report on the Flora of the Bahamas;—Second Report on the Physiology of the Lymphatic System;—Report on the Microscopic Structure of the Older Rocks of Anglesey;—Report on our present knowledge of the Flora of China;—Second Report of the Committee for taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon;—Eighth Report on the Earthquake and Volcanic Phenomena of Japan;—Report on the present state of our knowledge of the Zoology and Botany of the West India Islands, and the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Second Report on our Experimental Knowledge of the Properties of Matter with respect to Volume, Pressure, Temperature, and Specific Heat;—Report on the advisability and possibility of establishing in other parts of the country observations upon the prevalence of Earth Tremors similar to those now being made in Durham;—The Relations between Sliding Scales and Economic Theory;—Index-numbers as illustrating the Progressive Exports of British Produce and Manufactures;—The Friction of Metal Coils;—Sur l'application de l'analyse spectrale à la mécanique moléculaire et sur les spectres de l'oxygène;—A List of Works referring to British Mineral and Thermal Waters;—Report on the Rate of Erosion of the Sea-coasts of England and Wales, and the Influence of the Artificial Abstraction of Shingle or other material in that Action.

Together with the Transactions of the Sections, Sir F. J. Bramwell's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE FIFTY-NINTH MEETING, at Newcastle-upon-Tyne, September 1889, *Published at* £1 4*s*.

CONTENTS:—Fifth Report of the Committee for promoting Tidal Observations in Canada;—Report on the Molecular Phenomena connected with the Magnetisation of Iron;—Report on the Collection and Identification of Meteoric Dust;—Eighteenth Report on Underground Temperature;—Fifth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Second Report of the Committee to arrange an investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom, in co-operation with the local Societies represented on the Association;—Report on the proposals of M. Tondini de Quarenghi relative to the Unification of Time, and the adoption of a Universal Prime Meridian;—Fifth Report on

the best means of Comparing and Reducing Magnetic Observations;—Report on the best method of establishing International Standards for the Analysis of Iron and Steel;—Third Report on the Investigation of the Properties of Solutions; —Third Report on the Bibliography of Solution;—Report (Provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report of the Committee appointed to confer with the Committee of the American Association for the Advancement of Science with a view of forming a Uniform System of recording the results of Water Analysis;—Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Seventh Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the Flora of the Carboniferous Rocks of Lancashire and West Yorkshire;—Report on an Ancient Sea-beach near Bridlington Quay;—Fifteenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Higher Eocene Beds of the Isle of Wight;—Third Report on the 'Manure' Gravels of Wexford;—Second Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Second Report on the development of the Oviduct and connected structures in certain freshwater Teleostei; —Report on the Occupation of a Table at the Zoological Station at Naples;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net, for opening and closing under water;—Third Report on our present Knowledge of the Flora of China;—Report on the steps taken for the investigation of the Natural History of the Friendly Islands, or other groups in the Pacific, visited by H.M.S. 'Egeria';—Report of the Committee for making a digest of the Observations on the Migration of Birds;—Report of the Committee for taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon;—Seventeenth Report on the Erratic Blocks of England, Wales, and Ireland;—Third Report on the Physiology of the Lymphatic System;—Report on the Teaching of Science in Elementary Schools;—Third Report on the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard;—Report as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief forms in which the Money is employed, and the amount annually used in the Arts;—Report on the Geography and Geology of the Atlas Ranges in the Empire of Morocco;—Fourth Report on Isomeric Naphthalene Derivatives;—Report on the Habits and Customs and Physical Characteristics of the Nomad Tribes of Asia Minor, and on the excavation of Sites of ancient occupation;—Report on the effects of different Occupations and Employments on the Physical Development of the Human Body;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Report of the Corresponding Societies Committee;—Fourth Report on Electrolysis in its Physical and Chemical Bearings;—Report on the Absorption Spectra of Pure Compounds;—Second Report on the present methods of teaching Chemistry;—Third Report on the Influence of Silicon on the properties of Steel;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Ninth Report on the Earthquake and Volcanic Phenomena of Japan;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Third Report on the Prehistoric Inhabitants of the British Islands;—Report on the Development of Graphic Methods in Mechanical Science;—Report on the investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report of the Committee for continuing the Bibliography of Spectroscopy;—Report of the Committee for calculating the Anthropological Measurements taken at Bath;—Second Report on the Disappearance of Native Plants from their Local Habitats;—The Incidence and Effects of Import and Export Duties;—Experiments upon the Transmission of Power by Compressed Air in Paris (Popp's System); —The Comtist Criticism of Economic Science;—On the Advisability of assigning Marks for Bodily Efficiency in the Examination of Candidates for the Public Services;—On the Principle and Methods of assigning Marks for Bodily Efficiency;—Experiments at Eton College on the Degree of Concordance between different Examiners in assigning Marks for Physical Qualifications;—Fifth Report on the North-Western Tribes of the Dominion of Canada.

Together with the Transactions of the Sections, Professor W. H. Flower's Address and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTIETH MEETING, at Leeds, August 1890, *Published at £1 4s.*

CONTENTS:—Report of the Corresponding Societies Committee;—Third Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom, in co-operation with the Local Societies represented on the Association;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Fifth Report on Electrolysis in its Physical and Chemical Bearings;—Sixth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report on Molecular Phenomena associated with the Magnetisation of Iron;—Tenth Report on the Earthquake and Volcanic Phenomena of Japan;—Sixth Report on the best means of comparing and reducing Magnetic Observations;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Sixth Report of the Committee for promoting Tidal Observations in Canada;—Report on the present state of our Knowledge in Electrolysis and Electro-chemistry;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Report on the Bibliography of Spectroscopy;—Fourth Report on the Influence of Silicon on the Properties of Iron and Steel;—Second Report on the best method of establishing an International Standard for the Analysis of Iron and Steel;—Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Third Report on the present Methods of Teaching Chemistry;—Fourth Report on the Properties of Solutions;—Fourth Report on the Bibliography of Solution;—Discussion on the Theory of Solution;—Provisional Report on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report on the Absorption Spectra of Pure Compounds;—Report on the best methods for the Registration of all Type Specimens of Fossils in the British Isles;—Eighteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Sixteenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Final Report on an Ancient Sea-beach near Bridlington Quay;—Report on the Cretaceous Polyzoa;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Fourth and final Report on the 'Manure' Gravels of Wexford;—Eighth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Third Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for making a Digest of the Observations on the Migration of Birds;—Third Report on the Disappearance of Native Plants from their Local Habitats;—Fourth Report of the Committee for taking steps for the establishment of a Botanical Station at Peradeniya, Ceylon;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—The probable Effects on Wages of a general Reduction in the Hours of Labour;—Fourth Report on the best methods of ascertaining and measuring Variations in the Value of the Monetary Standard;—Report on the teaching of Science in Elementary Schools;—Fourth Report as to the Statistical Data available for determining the amount of the Precious Metals in use as Money in the principal Countries, the chief Forms in which the Money is employed, and the Amount annually used in the Arts;—On some new Telemeters or Range-finders;—Second Report on the Investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report on the Geography and the Habits, Customs, and Physical Characters of the Nomad Tribes of Asia Minor and Northern Persia, and on the excavation of Sites of Ancient Occupation;—Report on the Habits, Customs, Physical Characters, and Religions of the Natives of India;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Fourth Report on the Prehistoric Inhabitants of the British Islands;—Report on

the Calculation of the Anthropological Measurements taken at Newcastle;—Sixth Report on the North-Western Tribes of the Dominion of Canada.

Together with the Transactions of the Sections, Sir F. A. Abel's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-FIRST MEETING, at Cardiff, August 1891, *Published at £1 4s.*

CONTENTS:—Report of the Corresponding Societies Committee;—Report on the present state of our knowledge of Thermodynamics, specially with regard to the Second Law;—Sixth Report on Electrolysis in its Physical and Chemical Bearings;—Eleventh Report on the Earthquake and Volcanic Phenomena of Japan;—Second Report of the Committee for calculating Tables of certain Mathematical Functions, and, if necessary, taking steps to carry out the Calculations, and publishing the results in an accessible form;—Fifth Report on the application of Photography to the Elucidation of Meteorological Phenomena;—Report on the Discharge of Electricity from Points;—Report of the Committee for co-operating with the Scottish Meteorological Society in making Meteorological Observations on Ben Nevis;—Third (interim) Report on the various Phenomena connected with the Recalescent Points in Iron and other Metals;—Second (interim) Report of the Committee for co-operating with Dr. Kerr in his Researches on Electro-optics;—Report of the Committee for co-operating with Dr. C. Piazzi Smyth in his Researches on the Ultra-violet Rays of the Solar Spectrum;—Report on the best means of Comparing and Reducing Magnetic Observations;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Interim Report of the Committee for carrying on the Tables connected with the Pellian Equation from the Point where the work was left by Degen in 1817;—Seventh Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on the Preparation of a new series of Wave-length Tables of the Spectra of the Elements and Compounds;—Interim Report on the Action of Light upon Dyed Colours;—Report (provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Third Report on the Bibliography of Spectroscopy;—Fifth Report on Isomeric Naphthalene Derivatives;—Fifth Report on the Bibliography of Solution;—Third Report on the best method of establishing an International Standard for the Analysis of Iron and Steel;—Provisional Report on the direct formation of Haloid Compounds from pure materials;—Report (provisional) on the Absorption Spectra of Pure Compounds;—Nineteenth Report on the Erratic Blocks of England, Wales, and Ireland;—Second Report on the Registration of all the Type Specimens of British Fossils;—Seventeenth Report on the Circulation of Underground Waters in the Permeable Formations of England and Wales, and the Quantity and Character of the Water supplied to various Towns and Districts from these Formations;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Second Report on the collection, preservation, and systematic registration of Photographs of Geological Interest in the United Kingdom;—Report on the advisability and possibility of establishing in other parts of the country Observations upon the Prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions;—Report of the Committee for working the very Fossiliferous Transition Bed between the Middle and Upper Lias in Northamptonshire, in order to obtain a more clear idea of its fauna, and to fix the position of certain species of Fossil Fish, and more fully investigate the horizon on which they occur;—Report of the Committee to complete the investigation of the Cave at Elbolton, near Skipton, in order to ascertain whether Remains of Palæolithic Man occur in the Lower Cave Earth;—Report of the Committee for carrying on excavations at Oldbury Hill, near Ightham, in order to ascertain the existence or otherwise of Rock-shelters at this spot;—Fourth Report on the present state of our knowledge of the Zoology and Botany of the West India Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Draft Report on the present state of our knowledge of the Zoology of the Sandwich Islands, and on the steps taken to investigate ascertained deficiencies in the Fauna;—Fifth Report of the Committee for taking steps for the establishment of a Botanical Laboratory at Peradeniya, Ceylon;—Fourth Report on the Disappearance of Native Plants from their Local Habitats;—Report of the Committee for making a digest of the observations on the Migration of Birds at Lighthouses and Light-vessels, which have been carried

on by the Migration Committee of the British Association;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth; —Report on the occupation of a Table at the Zoological Station at Naples;—Report of the Committee for improving and experimenting with a Deep-sea Tow-net for opening and closing under water;—Report on the teaching of Science in Elementary Schools;—Third Report on the investigation of the Action of Waves and Currents on the Beds and Foreshores of Estuaries by means of Working Models;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Seventh Report on the North-western Tribes of the Dominion of Canada;—Fifth Report on the Prehistoric Inhabitants of the British Islands;—Fourth and Final Report of the Committee to arrange an Investigation of the Seasonal Variations of Temperature in Lakes, Rivers, and Estuaries in various parts of the United Kingdom in co-operation with the local societies represented on the Association;—On the Capture of Comets by Planets, especially their Capture by Jupiter;—The Recent Progress of Agriculture in India.

Together with the Transactions of the Sections, Dr. Huggins's Address, and Resolutions of the General Committee of the Association.

REPORT OF THE SIXTY-SECOND MEETING, at Edinburgh, August 1892, *Published at £1 4s.*

CONTENTS:—Report of the Corresponding Societies Committee;—Report on Meteorological Observations on Ben Nevis;—Seventh Report on Electrolysis in its Physical and Chemical Bearings;—Report on the Phenomena accompanying the Discharge of Electricity from Points;—Second Report on the Ultra-violet Rays of the Solar Spectrum;—Second Report on the Application of Photography to the Elucidation of Meteorological Phenomena;—Twelfth Report on the Earthquake and Volcanic Phenomena of Japan;—Nineteenth Report on the Rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water;—Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements;—Report on Electro-optics;—Eighth Report on the best methods of recording the direct Intensity of Solar Radiation;—Report on Constants and Units;—On the Application of Interference Methods to Spectroscopic Measurements;—Fourth Report on establishing an International Standard for the Analysis of Iron and Steel;—Sixth Report on Isomeric Naphthalene Derivatives;—Fourth Report on the Bibliography of Spectroscopy;—Report on the Action of Light on the Hydracids of the Halogens in presence of Oxygen;—Report on Wave-length Tables of the Spectra of the Elements and Compounds;—Sixth Report on the Bibliography of Solution;—Sixth Report on the Nature of Solution;—Report (provisional) on the Formation of Haloids from pure Materials;—Report (provisional) on the Influence of the Silent Discharge of Electricity on Oxygen and other Gases;—Report (provisional) on the Action of Light upon Dyed Colours;—Report on the Proximate Constituents of the various kinds of Coal;—Eighteenth Report on the Circulation of the Underground Waters in the Permeable Formations of England, and the Quality and Quantity of the Waters supplied to various Towns and Districts from these Formations;—Report on the Investigation of the Cave at Elbolton;—Twentieth Report on Erratic Blocks;—Third Report on the Registration of the Type Specimens of British Fossils;—Third Report on the Collection, Preservation, and Systematic Registration of Photographs of Geological Interest;—Ninth Report on the Fossil Phyllopoda of the Palæozoic Rocks;—Report on the Cretaceous Polyzoa;—Report on the Volcanic Phenomena of Vesuvius and its neighbourhood;—Report on the advisability and possibility of establishing in other parts of the country observations upon the prevalence of Earth Tremors similar to those now being made in Durham in connection with coal-mine explosions;—Report on work done at the Zoological Station at Naples;—Fifth Report on the present state of our Knowledge of the Zoology and Botany of the West India Islands, and the steps taken to investigate ascertained deficiencies in the Fauna and Flora;—Second Report on the present state of our Knowledge of the Zoology of the Sandwich Islands, and the steps taken to investigate ascertained deficiencies in the Fauna;—Report on the occupation of a Table at the Laboratory of the Marine Biological Association at Plymouth;—Sixth Report on the establishment of a Botanical Laboratory at Peradeniya, Ceylon;—Report of the Committee for making a Digest

of the Observations on the Migration of Birds at Lighthouses and Light-vessels;—Report on a Deep-sea Tow-net for opening and closing under Water;—Report on proposals for the Legislative Protection of Wild Birds' Eggs; Report on the Climatological and Hydrographical Conditions of Tropical Africa;—Report on the Teaching of Science in Elementary Schools;—Second Report on the Development of Graphic Methods of Mechanical Science;—Shield Tunnelling in Loose Ground under Water Pressure, with special reference to the Vyrnwy Aqueduct Tunnel under the Mersey;—Report of the Committee for editing a new Edition of 'Anthropological Notes and Queries';—Report on the Ruins of Mashonaland and the Habits and Customs of the inhabitants;—Report on the Prehistoric and Ancient Remains of Glamorganshire;—Eighth Report on the Physical Characters, Languages, and Industrial and Social Condition of the North-Western Tribes of the Dominion of Canada;—Report on the Habits, Customs, Physical Characteristics, and Religions of the Natives of India;—Report on the work done in the Anthropometric Laboratory.

Together with the Transactions of the Sections, Sir Archibald Geikie's Address, and Resolutions of the General Committee of the Association.

The following Publications are also on sale at the Office of the Association:—

Index to the Reports, 1831–1860, 12*s.* (carriage included).

Index to the Reports, 1861–1890, 15*s.* (carriage $4\frac{1}{2}$*d.*)

Lalande's Catalogue of Stars, £1 1*s.*

Rules of Zoological Nomenclature, 1*s.*

On the Regulation of Wages by means of Lists in the Cotton Industry:—Spinning, 2*s.*; Weaving, 1*s.*

Report on the best means for promoting Scientific Education in Schools, 6*d.*

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Report of the Committee for constructing and issuing Practical Standards for use in Electrical Measurements, 6*d.*

Second Report on the Development of Graphic Methods in Mechanical Science, 1*s.*

BRITISH ASSOCIATION

FOR

THE ADVANCEMENT OF SCIENCE.

LIST

OF

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CORRECTED TO JANUARY 31, 1894.

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1893.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members of the GENERAL COMMITTEE are printed in SMALL CAPITALS.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of residence should be sent to the Assistant General Secretary

Year of Election.

1887. *Abbe, Professor Cleveland. Weather Bureau, Department of Agriculture, Washington, U.S.A.
1881. *Abbott, R. T. G. Whitley House, Malton.
1887. ‡Abbott, T. C. Eastleigh, Queen's-road, Bowdon, Cheshire.
1863. *ABEL, Sir FREDERICK AUGUSTUS, Bart., K.C.B., D.C.L., D.Sc., F.R.S., V.P.C.S., President of the Government Committee on Explosives. The Imperial Institute, Imperial Institute-road, London, S.W.
1886. ‡ABERCROMBY, The Hon. RALPH, F.R.Met.Soc. 21 Chapel-street, Belgrave-square, London, S.W.
1891. §ABERDARE, The Right Hon. Lord, G.C.B., F.R.S., F.R.G.S. Duffryn, Mountain Ash, South Wales.
1885. *ABERDEEN, The Right Hon. the Earl of, LL.D. 37 Grosvenor-square, London, W.
1885. ‡Aberdeen, The Countess of. 37 Grosvenor-square, London, W.
1885. ‡Abernethy, David W. Ferryhill Cottage, Aberdeen.
1863. *ABERNETHY, JAMES, M.Inst.C.E., F.R.S.E. 4 Delahay-street, Westminster, S.W.

Year of
Election.

1885. ‡Abernethy, James W. 2 Rubislaw-place, Aberdeen.
1873. *ABNEY, Captain W. DE W., R.E., C.B., D.C.L., F.R.S., F.R.A.S., F.C.S. Willeslie House, Wetherby-road, South Kensington, London, S.W.
1886. ‡Abraham, Harry. 147 High-street, Southampton.
1877. ‡Ace, Rev. Daniel, D.D., F.R.A.S. Laughton, near Gainsborough, Lincolnshire.
1884. ‡Acheson, George. Collegiate Institute, Toronto, Canada.
1873. ‡Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.
1882. *Acland, Alfred Dyke. 38 Pont-street, Chelsea, London, S.W.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
1877. *Acland, Captain Francis E. Dyke, R.A. Woodmansterne Rectory, Banstead, Surrey.
1873. *Acland, Rev. H. D., M.A. Luccombe Rectory, Taunton.
1873. *ACLAND, Sir HENRY W. D., Bart., K.C.B., M.A., M.D., LL.D., F.R.S., F.R.G.S., Radcliffe Librarian and Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
1877. *Acland, Theodore Dyke, M.A. 74 Brook-street, London, W.
1860. ‡ACLAND, Sir THOMAS DYKE, Bart., M.A., D.C.L. Killerton, Exeter; and Athenæum Club, London, S.W.
1887. ‡ADAMI, J. G., B.A. New Museums, Cambridge.
1892. ‡Adams, David. Rockville, North Queensferry.
1884. ‡Adams, Frank Donovan. Geological Survey, Ottawa, Canada.
1876. ‡*Adams, James. 9 Royal-crescent West, Glasgow.*
1871. §Adams, John R. 2 Nutley-terrace, Hampstead, London, N.W.
1879. *ADAMS, Rev. THOMAS, M.A., D.C.L., Principal of Bishop's College, Lennoxville, Canada.
1877. ‡*Adams, William. 3 Sussex-terrace, Plymouth.*
1869. *ADAMS, WILLIAM GRYLLS, M.A., D.Sc., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 43 Notting Hill-square, London, W.
1879. ‡Adamson, Robert, M.A., LL.D., Professor of Logic in the University of Aberdeen.
1890. ‡Addyman, James Wilson, B.A. Belmont, Starbeck, Harrogate.
1890. ‡ADENEY, W. E., F.C.S. Royal University of Ireland, Earlsfort-terrace, Dublin.
1865. *Adkins, Henry. Northfield, near Birmingham.
1883. ‡Adshead, Samuel. School of Science, Macclesfield.
1884. ‡Agnew, Cornelius R. 266 Maddison-avenue, New York, U.S.A.
1887. ‡Agnew, William. Summer Hill, Pendleton, Manchester.
1884. ‡Aikins, Dr. W. T. Jarvis-street, Toronto, Canada.
1864. *Ainsworth, David, M.P. The Flosh, Cleator, Carnforth.
1871. *Ainsworth, John Stirling. Harecroft, Cumberland.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Carnforth.
1891. *Aisbitt, M. W. Mountstuart-square, Cardiff.
1871. §Aitken, John, F.R.S., F.R.S.E. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1884. *Alabaster, H. Hazeldene, Wood-vale, Honor Oak, London, S.E.
1886. *Albright, G. S. The Elms, Edgbaston, Birmingham.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B., D.C.L., F.R.G.S. The Athenæum Club, Pall Mall, London, S.W.
1891. ‡Alexander, D. T. Dynas Powis, Cardiff.
1883. ‡Alexander, George. Kildare-street Club, Dublin.
1888. *Alexander, Patrick Y. Experimental Works, Bath.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.

Year of Election.

1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1891. *Alford, Charles J., F.G.S. Coolivin, Hawkwood-road, Boscombe, Hants.
1883. ‡Alger, Miss Ethel. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, W. H. The Manor House, Stoke Damerel, South Devon.
1883. ‡Alger, Mrs. W. H. The Manor House, Stoke Damerel, South Devon.
1867. ‡Alison, George L. C. Dundee.
1885. ‡Allan, David. West Cults, near Aberdeen.
1871. ‡Allan, G., M.Inst.C.E. 10 Austin Friars, London, E.C.
1871. ‡ALLEN, ALFRED H., F.C.S. 67 Surrey-street, Sheffield.
1887. *Allen, Arthur Ackland. Overbrook, Kersal, Manchester.
1879. *Allen, Rev. A. J. C. Melrose, Grange-road, Cambridge.
1887. *Allen, Charles Peter. Overbrook, Kersal, Manchester.
1888. §Allen, F. J. Mason College, Birmingham.
1884. ‡Allen, Rev. George. Shaw Vicarage, Oldham.
1891. ‡Allen, Henry A., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1887. §Allen, John. Kilgrimol School, St. Anne's-on-the-Sea, viâ Preston.
1878. ‡Allen, John Romilly. 5 Albert-terrace, Regent's Park, London, N.W.
1861. ‡Allen, Richard. Didsbury, near Manchester.
1887. *Allen, Russell. 2 Parkwood, Victoria Park, Manchester.
1891. ‡Allen, W. H. 24 Glenroy-street, Roath, Cardiff.
1889. ‡Allhusen, Alfred. Low Fell, Gateshead.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
1889. §Allhusen, Frank. Low Fell, Gateshead.
*ALLMAN, GEORGE J., M.D., LL.D., F.R.S., F.R.S.E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. Ardmore, Parkstone, Dorset.
1887. *Allnutt, J. W. F., M.A. 12 Chapel-row, Portsea, Hants.
1886. ‡Allport, Samuel. 50 Whittall-street, Birmingham.
1887. ‡Alward, G. L. 11 Hamilton-street, Grimsby, Yorkshire.
1873. ‡Ambler, John. North Park-road, Bradford, Yorkshire.
1891. ‡Ambrose, D. R. 4 Richmond-terrace, Cardiff.
1883. §Amery, John Sparke. Druid House, Ashburton, Devon.
1883. §Amery, Peter Fabyan Sparke. Druid House, Ashburton, Devon.
1884. ‡Ami, Henry. Geological Survey, Ottawa, Canada.
1885. ‡Anderson, Charles Clinton. 4 Knaresborough-place, Cromwell-road, London, S.W.
1850. ‡*Anderson, Charles William. Belvedere, Harrogate.*
1883. ‡Anderson, Miss Constance. 17 Stonegate, York.
1885. *Anderson, Hugh Kerr. Frognal Park, Hampstead, London, N.W.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1892. ‡Anderson, Joseph, LL.D. 8 Great King-street, Edinburgh.
1888. *Anderson, R. Bruce. 35A Great George-street, London, S.W.
1887. ‡Anderson, Professor R. J., M.D. Queen's College, Galway.
1889. ‡Anderson, Robert Simpson. Elswick Collieries, Newcastle-upon-Tyne.
1880. *ANDERSON, TEMPEST, M.D., B.Sc. 17 Stonegate, York.
1886. *ANDERSON, WILLIAM, D.C.L., F.R.S., M.Inst.C.E., Director-General of Ordnance Factories. Lesney House, Erith, Kent.
1880. ‡Andrew, Mrs. 126 Jamaica-street, Stepney, London, E.
1883. ‡Andrew, Thomas, F.G.S. 18 Southernhay, Exeter.
1891. ‡Andrews, Thomas. 163 Newport-road, Cardiff.
1880. *Andrews, Thornton, M.Inst.C.E. Cefn Eithen, Swansea.
1886. §Andrews, William, F.G.S. Steeple Croft, Coventry.

Year of Election.

1883. ‡Anelay, Miss M. Mabel. Girton College, Cambridge.
1877. §ANGELL, JOHN, F.C.S. 5 Beacons-field, Derby-road, Fallowfield, Manchester.
1886. ‡Annan, John, J.P. Whitmore Reans, Wolverhampton.
1886. ‡Ansell, Joseph. 38 Waterloo-street, Birmingham.
1878. ‡Anson, Frederick H. 15 Dean's-yard, Westminster, S.W.
Anthony, John, M.D. 6 Greenfield-crescent, Edgbaston, Birmingham.
1890. §Antrobus, J. Coutts. Eaton Hall, Congleton.
1886. ‡*Arblaster, Edmund, M.A. The Grammar School, Carlisle.*
1870. ‡Archer, Francis. 14 Cook-street, Liverpool.
1874. ‡Archer, William, F.R.S., M.R.I.A. 11 South Frederick-street, Dublin.
1884. *Archibald, E. Douglas. Care of Mr. F. Tate, 28 Market-street, Melbourne.
1851. ‡ARGYLL, His Grace the Duke of, K.G., K.T., D.C.L., F.R.S., F.R.S.E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inverary, Argyllshire.
1884. §Arlidge, John Thomas, M.D., B.A. The High Grove, Stoke-upon-Trent.
1883. §Armistead, Richard. 33 Chambres-road, Southport.
1883. *Armistead, William. 15 Rupert-street, Compton-road, Wolverhampton.
1887. ‡Armitage, Benjamin. Chomlea, Pendleton, Manchester.
1861. ‡Armitage, William. 95 Portland-street, Manchester.
1867. **Armitstead, George. Errol Park, Errol, N.B.*
1857. *ARMSTRONG, The Right Hon. Lord, C.B., LL.D., D.C.L., F.R.S. Jesmond Dene, Newcastle-upon-Tyne.
1879. *Armstrong, Sir Alexander, K.C.B., M.D., LL.D., F.R.S., F.R.G.S. The Albany, London, W.
1886. ‡ARMSTRONG, GEORGE FREDERICK, M.A., F.R.S.E., F.G.S., Regius Professor of Engineering in the University of Edinburgh. The University, Edinburgh.
1873. ‡ARMSTRONG, HENRY E., Ph.D., LL.D., F.R.S., Pres.C.S., Professor of Chemistry in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W. 55 Granville Park, Lewisham, S.E.
1876. ‡Armstrong, James. Bay Ridge, Long Island, New York, U.S.A.
1889. ‡Armstrong, John A. 32 Eldon-street, Newcastle-upon-Tyne.
1884. ‡Armstrong, Robert B. Junior Carlton Club, Pall Mall, London, S.W.
Armstrong, Thomas. Higher Broughton, Manchester.
1889. ‡Armstrong, Thomas John. 14 Hawthorn-terrace, Newcastle-upon-Tyne.
1893. §Arnold-Bemrose, H., M.A., F.G.S. 56 Friar-gate, Derby.
1870. ‡Arnott, Thomas Reid. Bramshill, Harlesden Green, London, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1886. ‡Ascough, Jesse. Patent Borax Company, Newmarket-street, Birmingham.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. Dundrum, Co. Dublin.
1889. §Ashley, Howard M. Airedale, Ferrybridge, Yorkshire.
1873. ‡*Ashton, John. Gorse Bank House, Windsor-road, Oldham.*
ASHTON, THOMAS, J.P. Ford Bank, Didsbury, Manchester.
1887. ‡Ashton, Thomas Gair, M.A. 36 Charlotte-street, Manchester.
1866. ‡Ashwell, Henry. Woodthorpe, Nottingham.

Year of Election.

*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
1887. ‡Ashworth, Mrs. Harriet. Thorne Bank, Heaton Moor, near Stockport.
Ashworth, Henry. Turton, near Bolton.
1888. *Ashworth, J. J. 39 Spring-gardens, Manchester.
1890. ‡Ashworth, J. Reginald. 20 King-street, Rochdale.
1887. ‡Ashworth, John Wallwork. Thorne Bank, Heaton Moor, near Stockport.
1887. ‡Aspland, Arthur P. Werneth Lodge, Gee Cross, near Manchester.
1875. *Aspland, W. Gaskell. Birchwood-grove, Burgess Hill, Sussex.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Theodore. 11 New-square, Lincoln's Inn, London, W.C.
1887. §Atkinson, Rev. C. Chetwynd, M.A. Fairfield House, Ashton-on-Mersey.
1865. *Atkinson, Edmund, Ph.D., F.C.S. Portesbery Hill, Camberley, Surrey.
1884. ‡Atkinson, Edward, Ph.D., LL.D. Brookline, Massachusetts, U.S.A.
1863. **Atkinson, G. Clayton.* 21 *Windsor-terrace, Newcastle-on-Tyne.*
1861. ‡Atkinson, Rev. J. A. Vicarage, Bolton.
1881. ‡Atkinson, J. T. The Quay, Selby, Yorkshire.
1881. ‡Atkinson, Robert William, F.C.S. 44 Loudoun-square, Cardiff.
1863. *Attfield, Professor J., M.A., Ph.D., F.R.S., F.C.S. 17 Bloomsbury-square, London, W.C.
1884. ‡Auchincloss, W. S. 209 Church-street, Philadelphia, U.S.A.
1886. ‡Aulton, A. D., M.D. Walsall.
1860. *Austin-Gourlay, Rev. William E. C., M.A. 11 Christ Church-road, Winchester.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1881. ‡Axon, W. E. A. Fern Bank, Higher Broughton, Manchester.
1888. ‡Ayre, Rev. J. W., M.A. 30 Green-street, Grosvenor-square, London, W.
1877. *Ayrton, W. E., F.R.S., Professor of Applied Physics in the City and Guilds of London Institute, Central Institution, Exhibition-road, London, S.W.

*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
1884. ‡Baby, The Hon. G. Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1883. *Backhouse, W. A. St. John's Wolsingham, near Darlington.
1887. *Bacon, Thomas Walter. 4 Lyndhurst-road, Hampstead, London, N.W.
1887. ‡Baddeley, John. 1 Charlotte-street, Manchester.
1881. ‡Baden-Powell, Sir George S., K.C.M.G., M.A., M.P., F.R.A.S., F.S.S. 8 St. George's-place, Hyde Park, London, S.W.
1877. ‡Badock, W. F. Badminton House, Clifton Park, Bristol.
1883. ‡Baildon, Dr. 65 Manchester-road, Southport.
1892. §Baildon, H. Bellyer. Duncliffe, Murrayfield, Edinburgh.
1883. *Bailey, Charles, F.L.S. Ashfield, College-road, Whalley Range, Manchester.
1893. §Bailey, Colonel F., Sec. R.Scot.G.S., F.R.G.S. Edinburgh.
1870. ‡Bailey, Dr. Francis J. 51 Grove-street, Liverpool.
1887. *Bailey, G. H., D.Sc., Ph.D. Owens College, Manchester.
1865. ‡Bailey, Samuel, F.G.S. Ashley House, Calthorpe-road, Edgbaston, Birmingham.

Year of Election.

1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1887. ‡Bailey, W. H. Summerfield, Eccles Old-road, Manchester.
1866. ‡Baillon, Andrew. British Consulate, Brest.
1878. ‡Baily, Walter. 176 Haverstock-hill, London, N.W.
1885. ‡BAIN, ALEXANDER, M.A., LL.D. Ferryhill Lodge, Aberdeen.
1873. ‡Bain, Sir James, M.P. 3 Park-terrace, Glasgow.
1885. ‡Bain, William N. Collingwood, Pollokshields, Glasgow.
1882. *BAKER, Sir BENJAMIN, K.C.M.G., LL.D., F.R.S., M.Inst.C.E. 2 Queen Square-place, Westminster, S.W.
1886. ‡*Baker, Harry. 262 Plymouth-grove, Manchester.*
1891. ‡Baker, J. W. 50 Stacey-road, Cardiff.
1861. *Baker, John. The Gables, Buxton.
1881. ‡Baker, Robert, M.D. The Retreat, York.
1863. ‡Baker, William. 6 Taptonville, Sheffield.
1875. ‡BAKER, W. PROCTOR. Brislington, Bristol.
1881. ‡Baldwin, Rev. G. W. de Courcy, M.A. Lord Mayor's Walk, York.
1884. ‡Balete, Professor E. Polytechnic School, Montreal, Canada.
1871. ‡Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. ‡BALFOUR, ISAAC BAYLEY, M.A., D.Sc., M.D., F.R S., F.R.S.E., F.L.S., Professor of Botany in the University of Edinburgh. Inverleith House, Edinburgh.
1883. ‡Balfour, Mrs. I. Bayley. Inverleith House, Edinburgh.
1878. *Ball, Charles Bent, M.D. 24 Merrion-square, Dublin.
1866. *BALL, Sir ROBERT STAWELL, LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1878. ‡BALL, VALENTINE, C.B., M.A., LL.D., F.R.S., F.G.S., Director of the Museum of Science and Art, Dublin.
1883. *Ball, W. W. Rouse, M.A. Trinity College, Cambridge.
1886. ‡Ballantyne, J. W., M.B. 24 Melville-street, Edinburgh.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1890. §Bamford, Harry, B.Sc. The Owens College, Manchester.
1882. ‡Bance, Major Edward. Limewood, The Avenue, Southampton.
1884. ‡Barbeau, E. J. Montreal, Canada.
1866. ‡Barber, John. Long-row, Nottingham.
1884. ‡Barber, Rev. S. F. West Raynham Rectory, Swaffham, Norfolk.
1890. *Barber-Starkey, W. J. S. Aldenham Park, Bridgnorth, Salop.
1861. *Barbour, George. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1876. *Barclay, Robert. 21 Park-terrace, Glasgow.
1887. *Barclay, Robert. Springfield, Kersal, Manchester.
1886. ‡Barclay, Thomas. 17 Bull-street, Birmingham.
1881. ‡Barfoot, William, J.P. Whelford-place, Leicester.
1882. ‡Barford, J. D. Above Bar, Southampton.
1886. ‡Barham, F. F. Bank of England, Birmingham.
1890. ‡Barker, Alfred, M.A., B.Sc. Aske's Hatcham School, New Cross, London, S.E.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Nottingham.
1879. ‡Barker, Elliott. 2 High-street, Sheffield.
1882. *Barker, Miss J. M. Hexham House, Hexham.

Year of Election.

1879. *Barker, Rev. Philip C., M.A., LL.B. Boroughbridge Vicarage, Bridgwater.
1865. ‡*Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.*
1870. ‡Barkly, Sir Henry, G.C.M.G., K.C.B., F.R.S., F.R.G.S. 1 Bina-gardens, South Kensington, London, S.W.
1889. ‡Barkus, Dr. B. 3 Jesmond-terrace, Newcastle-upon-Tyne.
1886. ‡Barling, Gilbert. 85 Edmund-street, Edgbaston, Birmingham.
1873. ‡Barlow, Crawford, B.A., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1889. §Barlow, H. W. L. Holly Bank, Croftsbank-road, Urmston, near Manchester.
1883. ‡Barlow, J. J. 37 Park-street, Southport.
1878. ‡Barlow, John, M.D., Professor of Physiology in Anderson's College, Glasgow.
1883. ‡Barlow, John R. Greenthorne, near Bolton.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
1885. ‡Barlow, William, F.G.S. Hillfield, Muswell Hill, London, N.
1873. ‡Barlow, William Henry, F.R.S., M.Inst.C.E. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1881. ‡Barnard, William, LL.B. Harlow, Essex.
1889. ‡Barnes, J. W. Bank, Durham.
1868. §Barnes, Richard H. Heatherlands, Parkstone, Dorset.
1884. ‡Barnett, J. D. Port Hope, Ontario, Canada.
1886. ‡*Barnsley, Charles H. 32 Duchess-road, Edgbaston, Birmingham.*
1881. ‡Barr, Archibald, D.Sc., M.Inst.C.E. The University, Glasgow.
1890. ‡Barr, Frederick H. 4 South-parade, Leeds.
1859. ‡Barr, Lieut.-General. Apsleytoun, East Grinstead, Sussex.
1891. §Barrell, Frank R., M.A., Professor of Mathematics in University College, Bristol.
1883. ‡Barrett, John Chalk. Errismore, Birkdale, Southport.
1883. ‡Barrett, Mrs. J. C. Errismore, Birkdale, Southport.
1860. ‡Barrett, T. B. 20 Victoria-terrace, Welshpool, Montgomery.
1872. *Barrett, W. F., F.R.S.E., M.R.I.A., Professor of Physics in the Royal College of Science, Dublin.
1883. ‡Barrett, William Scott. Winton Lodge, Crosby, near Liverpool.
1887. ‡Barrington, Miss Amy. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington, R. M., M.A., LL.B., F.L.S. Fassaroe, Bray, Co. Wicklow.
1874. *Barrington-Ward, Mark J., M.A., F.L.S., F.R.G.S., H.M. Inspector of Schools. Thorneloe Lodge, Worcester.
1885. *Barron, Frederick Cadogan, M.Inst.C.E. Nervion, Beckenham-grove, Shortlands, Kent.
1881. §Barron, G. B., M.D. Summerseat, Southport.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1893. §Barrow, George, F.G.S. Geological Survey Office, Edinburgh.
1886. ‡Barrow, George William. Baldraud, Lancaster.
1886. ‡Barrow, Richard Bradbury. Lawn House, 13 Ampton-road, Edgbaston, Birmingham.
1886. ‡Barrows, Joseph. The Poplars, Yardley, near Birmingham.
1886. ‡Barrows, Joseph, jun. Ferndale, Harborne-road, Edgbaston, Birmingham.
1858. ‡Barry, Right Rev. Alfred, D.D., D.C.L. The Cloisters, Windsor.
1862. *Barry, Charles. 1 Victoria-street, London, S.W.
1883. ‡Barry, Charles E. 1 Victoria-street, London, S.W.
1875. ‡Barry, John Wolfe, M.Inst.C.E. 23 Delahay-street, Westminster, S.W.

Year of Election.

1881. ‡Barry, J. W. Duncombe-place, York.
1884. *Barstow, Miss Frances. Garrow Hill, near York.
1890. *Barstow, J. J. Jackson. The Lodge, Weston-super-Mare.
1890. *Barstow, Mrs. The Lodge, Weston-super-Mare.
1858. *Bartholomew, Charles. Castle Hill House, Ealing, Middlesex, W.
1892. §Bartholomew, John George, F.R.S.E., F.R.G.S. 12 Blacket-place, Edinburgh.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1884. ‡Bartlett, James Herbert. 148 Mansfield-street, Montreal, Canada.
1873. ‡Bartley, George C. T., M.P. St. Margaret's House, Victoria-street, London, S.W.
1892. ‡Barton, Miss. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1893. §Barton, Edwin H., B.Sc. Colwick Vale, Nottingham.
1884. ‡Barton, H. M. Foster-place, Dublin.
1852. ‡Barton, James. Farndreg, Dundalk.
1892. ‡Barton, William. 4 Glenorchy-terrace, Mayfield, Edinburgh.
1887. ‡Bartrum, John S. 13 Gay-street, Bath.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1882. *Basing, The Right Hon. Lord, F.R.S. 74 St. George's-square, London, S.W.
1876. ‡Bassano, Alexander. 12 Montagu-place, London, W.
1876. ‡Bassano, Clement. Jesus College, Cambridge.
1888. *Basset, A. B., M.A., F.R.S. Chapel Place Mansions, 322 Oxford-street, London, W.
1891. ‡Bassett, A. B. Cheverell, Llandaff.
1866. *Bassett, Henry. 26 Belitha-villas, Barnsbury, London, N.
1889. ‡Bastable, Professor C. F., M.A., F.S.S. 6 Trevelyan-terrace, Rathgar, Co. Dublin.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡Bastian, H. Charlton, M.A., M.D., F.R.S., F.L.S., Professor of the Principles and Practice of Medicine in University College, London. 8a Manchester-square, London, W.
1889. ‡Batalha-Reis, J. Portuguese Consulate, Newcastle-upon-Tyne.
1883. ‡Bateman, A. E., C.M.G. Board of Trade, London, S.W.
1873. *Bateman, Daniel. Wissahickon, Philadelphia, U.S.A.
1868. ‡Bateman, Sir F., M.D., LL.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.R.G.S., F.L.S. Home House, Worthing.
1889. ‡Bates, C. J. Heddon, Wylam, Northumberland.
1884. ‡Bateson, William, B.A. St. John's College, Cambridge.
1851. ‡Bath and Wells, The Right Rev. Lord Arthur Hervey, Lord Bishop of, D.D. The Palace, Wells, Somerset.
1881. *Bather, Francis Arthur, M.A., F.G.S. 207 Harrow-road, London, W.
1836. ‡Batten, Edmund Chisholm. Thorn Falcon, near Taunton, Somerset.
1867. *Battersea, The Right Hon. Lord, F.L.S. Travellers' Club, Pall Mall, London, S.W.
1863. §Bauerman, H., F.G.S. 9 Hazlebourne-gardens, Cavendish-road, Balham, London, S.W.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1892. §Bayly, F. W. Royal Mint, London, E.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near Plymouth.
1876. *Baynes, Robert E., M.A. Christ Church, Oxford.
1887. *Baynes, Mrs. R. E. 2 Norham-gardens, Oxford.
1887. ‡*Baynton, Alfred. 28 Gilda Brook Park, Eccles, Manchester.*
1883. *Bazley, Gardner. Hatherop Castle, Fairford, Gloucestershire.

Year of Election.

Bazley, Sir Thomas Sebastian, Bart., M.A. Hatherop Castle, Fairford, Gloucestershire.

1886. ‡Beale, C. Calle Progress No. 83, Rosario de Santa Fé, Argentine Republic.

1886. ‡Beale, Charles G. Maple Bank, Edgbaston, Birmingham.

1860. *BEALE, LIONEL S., M.B., F.R.S., Professor of the Principles and Practice of Medicine in King's College, London. 61 Grosvenor-street, London, W.

1882. §Beamish, Lieut.-Colonel A. W., R.E. 27 Philbeach-gardens, London, S.W.

1884. ‡Beamish, G. H. M. Prison, Liverpool.

1872. ‡Beanes, Edward, F.C.S. Moatlands, Paddock Wood, Brenchley, Kent.

1883. ‡*Beard, Mrs. 13 South-hill-road, Toxteth Park, Liverpool.*

1889. §Beare, Professor T. Hudson, F.R.S.E. University College, London, W.C.

1887. ‡Beaton, John, M.A. 219 Upper Brook-street, Chorlton-on-Medlock, Manchester.

1842. *Beatson, William. Ash Mount, Rotherham.

1888. ‡*Beatson, W. B., M.D. 11 Cavendish-place, Bath.*

1889. ‡Beattie, John. 5 Summerhill-grove, Newcastle-upon-Tyne.

1855. *Beaufort, W. Morris, F.R.A.S., F.R.G.S., F.R.M.S., F.S.S. 18 Piccadilly, London, W.

1886. ‡Beaugrand, M. H. Montreal.

1861. *Beaumont, Rev. Thomas George. Oakley Lodge, Leamington.

1887. *Beaumont, W. J. Emmanuel College, Cambridge.

1885. §BEAUMONT, W. W., M.Inst.C.E., F.G.S. Melford, Palace-road, Tulse Hill, London, S.W.

1871. *Beazley, Lieut.-Colonel George G. 74 Redcliffe-square, London, S.W.

1887. *BECKETT, JOHN HAMPDEN. Corbar Hill House, Buxton, Derbyshire.

1885. §BEDDARD, FRANK E., M.A., F.R.S., F.Z.S., Prosector to the Zoological Society of London. Society's Gardens, Regent's Park, London, N.W.

1870. §BEDDOE, JOHN, M.D., F.R.S. The Chantry, Bradford-on-Avon.

1858. §Bedford, James. Woodhouse Cliff, near Leeds.

1890. ‡Bedford, James E., F.G.S. Clifton-villas, Cardigan-road, Leeds.

1891. §Bedlington, Richard. Gadlys House, Aberdare.

1878. ‡BEDSON, P. PHILLIPS, D.Sc., F.C.S., Professor of Chemistry in the College of Physical Science, Newcastle-upon-Tyne.

1884. ‡Beers, W. G., M.D. 34 Beaver Hall-terrace, Montreal, Canada.

1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford, Yorkshire.

1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.

1891. *Belinfante, L. L., B.Sc., Assist.-Sec. G.S. Geological Society, Burlington House, London, W.

1892. ‡Bell, A. Beatson. 143 Princes-street, Edinburgh.

1873. ‡Bell, Asahel P. 32 St. Anne's-street, Manchester.

1871. ‡Bell, Charles B. 6 Spring-bank, Hull.

1884. ‡Bell, Charles Napier. Winnipeg, Canada.

Bell, Frederick John. Woodlands, near Maldon, Essex.

1860. ‡Bell, Rev. George Charles, M.A. Marlborough College, Wilts.

1862. *BELL, Sir ISAAC LOWTHIAN, Bart., LL.D., F.R.S., F.C.S., M.Inst.C.E. Rounton Grange, Northallerton.

1875. ‡Bell, James, C.B., D.Sc., Ph.D., F.R.S., F.C.S. The Laboratory, Somerset House, London, W.C.

1891. ‡Bell, James. Bangor Villa, Clive-road, Cardiff.

Year of Election.

1871. *BELL, J. CARTER, F.C.S. Bankfield, The Cliff, Higher Broughton, Manchester.
1883. *Bell, John Henry. Dalton Lees, Huddersfield.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
1876. ‡Bell, R. Bruce, M.Inst.C.E. 203 St. Vincent-street, Glasgow.
1867. ‡Bell, Thomas. Belmont, Dundee.
1888. *Bell, Walter George, M.A. Trinity Hall, Cambridge.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1882. ‡Bellingham, William. 15 Killieser-avenue, Telford Park, Streatham Hill, London, S.W.
1893. §BELPER, The Right Hon. Lord, LL.M. Kingston, Nottinghamshire.
1884. ‡Bemrose, Joseph. 15 Plateau-street, Montreal, Canada.
1886. §Benger, Frederick Baden, F.I.C., F.C.S. The Grange, Knutsford, Cheshire.
1885. ‡BENHAM, WILLIAM BLAXLAND, D.Sc. University College, London, W.C.
1891. §Bennett, Alfred Rosling. 22 St. Alban's-road, Harlesden, London, N.W.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1836. ‡Bennett, Henry. Bedminster, Bristol.
1887. ‡*Bennett, James M. St. Mungo Chemical Company, Ruckhill, Glasgow.*
1881. ‡Bennett, John R. 16 West Park, Clifton, Bristol.
1883. *Bennett, Laurence Henry. Bedminster, Bristol.
1881. ‡Bennett, Rev. S. H., M.A. St. Mary's Vicarage, Bishopshill Junior, York.
1870. *Bennett, William. Oak Hill Park, Old Swan, near Liverpool.
1887. ‡Bennion, James A., M.A. 1 St. James'-square, Manchester.
1889. ‡Benson, John G. 12 Grey-street, Newcastle-upon Tyne.
1848. ‡Benson, Starling. Gloucester-place, Swansea.
1887. *Benson, Mrs. W. J. Care of Standard Bank of South Africa, Cape Town.
1863. ‡Benson, William. Fourstones Court, Newcastle-upon-Tyne.
1885. *BENT, J. THEODORE. 13 Great Cumberland-place, London, W.
1884. ‡Bentham, William. 724 Sherbrooke-street, Montreal, Canada.
1876. ‡*Bergius, Walter C. 9 Loudon-terrace, Hillhead, Glasgow.*
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1886. ‡Bernard, W. Leigh. Calgary, Canada.
1887. §Berry, William. Parklands, Bowdon, Cheshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, Sir HENRY, F.R.S. Denmark Hill, London, S.E.
1882. *Bessemer, Henry, jun. Town Hill Park, West End, Southampton.
1890. ‡Best, William Woodham. 31 Lyddon-terrace, Leeds.
1883. ‡*Bettany, Mrs. 33 Oakhurst-grove, East Dulwich-road, London, S.E.*
1880. *Bevan, Rev. James Oliver, M.A., F.G.S. The Vicarage, Vowchurch, Hereford.
1884. *Beverley, Michael, M.D. 54 Prince of Wales-road, Norwich.
1885. ‡Beveridge, R. Beath Villa, Ferryhill, Aberdeen.
1890. §Bevington, Miss Mary E. Merle Wood, Sevenoaks, Kent.
1863. ‡Bewick, Thomas John, F.G.S. Suffolk House, Laurence Pountney Hill, London, E.C.
1870. ‡Bickerton, A.W., F.C.S. Christchurch, Canterbury, New Zealand.
1888. *Bidder, George Parker. The Zoological Station, Naples.

Year of Election.

1885. *BIDWELL, SHELFORD, M.A., LL.B., F.R.S. Riverstone Lodge, Southfields, Wandsworth, Surrey, S.W.
1882. §Biggs, C. H. W., F.C.S. Glebe Lodge, Champion Hill, London, S.E.
1891. ‡Billups, J. E. 29 The Parade, Cardiff.
1886. ‡Bindloss, G. F. Carnforth, Brondesbury Park, London, N.W.
1887. *Bindloss, James B. Elm Bank, Eccles, Manchester.
1884. *Bingham, Lieut.-Colonel John E., J.P. Electric Works, Sheffield.
1881. ‡Binnie, Alexander R., M.Inst.C.E., F.G.S. London County Council, Spring-gardens, London, S.W.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
1880. ‡Bird, Henry, F.C.S. South Down, near Devonport.
1888. *Birley, Miss Caroline. Seedley-terrace, Pendleton, Manchester.
1887. *Birley, H. K. 13 Hyde-road, Ardwick, Manchester.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1892. ‡Bishop, Arthur W., Ph.D. Heriot Watt College, Edinburgh.
1883. ‡Bishop, John le Marchant. 100 Mosley-street, Manchester.
1885. ‡Bissett, J. P. Wyndem, Banchory, N.B.
1886. *Bixby, Captain W. H. War Department, Washington, U.S.A.
1889. ‡Black, W. 1 Lovaine-place, Newcastle-upon-Tyne.
1889. §Black, William. 12 Romulus-terrace, Gateshead.
1881. ‡Black, Surgeon-Major William Galt, F.R.C.S.E. Caledonian United Service Club, Edinburgh.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
1834. Blackburn, Bewicke. Calverley Park, Tunbridge Wells.
1876. ‡Blackburn, Hugh, M.A. Roshven, Fort William, N.B.
1884. ‡Blackburn, Robert. New Edinburgh, Ontario, Canada.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1877. ‡Blackie, J. Alexander. 17 Stanhope-street, Glasgow.
1859. ‡Blackie, John S., M.A., Emeritus Professor of Greek in the Unisity of Edinburgh. 9 Douglas-crescent, Edinburgh.
1876. ‡Blackie, Robert. 7 Great Western-terrace, Glasgow.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1884. ‡Blacklock, Frederick W. 25 St. Famille-street, Montreal, Canada.
1883. ‡Blacklock, Mrs. Sea View, Lord-street, Southport.
1888. ‡Blaine, R. S., J.P. Summerhill Park, Bath.
1883. ‡Blair, Mrs. Oakshaw, Paisley.
1892. ‡Blair, Alexander. 35 Moray-place, Edinburgh.
1892. ‡Blair, John. 9 Ettrick-road, Edinburgh.
1863. ‡Blake, C. Carter, D.Sc. 28 Townshend-road, Regent's Park, London, N.W.
1886. ‡Blake, Dr. James. San Francisco, California.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S., F.R.G.S. 8 Devonshire-place, Portland-place, London, W.
1883. *BLAKE, Rev. J. F., M.A., F.G.S. 40 Loudoun-road, London, N.W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1891. ‡Blakesley, Thomas H., M.A., M.Inst.C.E. Royal Naval College, Greenwich, London, S.E.
1878. ‡Blakeney Rev. Canon, M.A., D.D. The Vicarage, Sheffield.
1886. ‡Blakie, John. The Bridge House, Newcastle, Staffordshire.
1861. §Blakiston, Matthew, F.R.G.S. Free Hills, Bursledon, Hants.
1887. ‡Blamires, George. Cleckheaton.
1881. §Blamires, Thomas H. Close Hill, Lockwood, near Huddersfield.
1884. *Blandy, William Charles, M.A. 1 Friar-street, Reading.
1869. ‡BLANFORD, W. T., LL.D., F.R.S., F.G.S., F.R.G.S. 72 Bedford-gardens, Campden Hill, London, W.

Year of Election.

1887. *Bles, A. J. S. Palm House, Park-lane, Higher Broughton, Manchester.
1887. *Bles, Edward J. The Laboratory, Citadel Hill, Plymouth.
1887. ‡Bles, Marcus S. The Beeches, Broughton Park, Manchester.
1884. *Blish, William G. Niles, Michigan, U.S.A.
1880. §Bloxam, G. W., M.A. Englefield Green, Surrey.
1888. §Bloxsom, Martin, B.A., Assoc.M.Inst.C.E. 73 Clarendon-road, Crumpsall, Manchester.
1883. ‡*Blumberg, Dr. 65 Hoghton-street, Southport.*
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Captain Richard. Bretlands, Chertsey, Surrey.
1885. ‡BLYTH, JAMES, M.A., F.R.S.E., Professor of Natural Philosophy in Anderson's College, Glasgow.
Blyth, B. Hall. 135 George-street, Edinburgh.
1883. ‡Blyth, Miss Phœbe. 3 South Mansion House-road, Edinburgh.
1867. *Blyth-Martin, W. Y. Blyth House, Newport, Fife.
1887. ‡Blythe, William S. 65 Mosley-street, Manchester.
1870. ‡Boardman, Edward. Oak House, Eaton, Norwich.
1887. *Boddington, Henry. Pownall Hall, Wilmslow, Manchester.
1889. ‡Bodmer, G. R., Assoc.M.Inst.C.E. 30 Walbrook, London, E.C.
1884. ‡Body, Rev. C. W. E., M.A. Trinity College, Toronto, Canada.
1887. *Boissevain, Gideon Maria. 4 Tesselschade-straat, Amsterdam.
1881. ‡Bojanowski, Dr. Victor de. 27 Finsbury-circus, London, E.C.
1876. ‡Bolton, J. C. Carbrook, Stirling.
Bond, Henry John Hayes, M.D. Cambridge.
1883. §Bonney, Frederic, F.R.G.S. Colton House, Rugeley, Staffordshire.
1883. §Bonney, Miss S. 23 Denning-road, Hampstead, London, N.W.
1871. *BONNEY, Rev. THOMAS GEORGE, D.Sc., LL.D., F.R.S., F.S.A., F.G.S., Professor of Geology in University College, London. 23 Denning-road, Hampstead, London, N.W.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1888. ‡Boon, William. Coventry.
1890. *Booth, Charles, F.S.S. 2 Talbot-court, Gracechurch-street, London, E.C.
1883. §Booth, James. Hazelhurst, Turton.
1893. §Booth, Jesse. Carlyle House, 18 Burns-street, Nottingham.
1883. ‡Booth, Richard. 4 Stone-buildings, Lincoln's Inn, London, W.C.
1876. ‡Booth, Rev. William H. St. Germain's-place, Blackheath, London, S.E.
1883. ‡Boothroyd, Benjamin. Rawlinson-road, Southport.
1876. *Borland, William. 260 West George-street, Glasgow.
1882. §Borns, Henry, Ph.D., F.C.S. 19 Alexandra-road, Wimbledon, Surrey.
1876. *Bosanquet, R. H. M., M.A., F.R.S., F.R.A.S., F.C.S. New University Club, St. James's-street, London, S.W.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
1881. §BOTHAMLEY, CHARLES H., F.I.C., F.C.S., Director of Technical Instruction, Somerset County Education Committee. Fernleigh, Haines Hill, Taunton, Somerset.
1867. ‡Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1887. ‡Bott, Dr. Owens College, Manchester.
1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1887. ‡Bottomley, James, D.Sc., B.A. 220 Lower Broughton-road, Manchester.

Year of Election.

1871. *BOTTOMLEY, JAMES THOMSON, M.A., F.R.S., F.R.S.E., F.C.S. 13 University-gardens, Glasgow.
1884. *Bottomley, Mrs. 13 University-gardens, Glasgow.
1892. ‡Bottomley, W. B. Ferncliffe, Morecambe.
1876. ‡*Bottomley, William, jun. 6 Rokeley-terrace, Hillhead, Glasgow.*
1890. §Boulnois, Henry Percy, M.Inst.C.E. Municipal Offices, Liverpool.
1883. ‡Bourdas, Isaiah. Dunoon House, Clapham Common, London, S.W.
1883. ‡BOURNE, A. G., D.Sc., F.L.S., Professor of Zoology in the Presidency College, Madras.
1893. §BOURNE, G. C., M.A., F.L.S. New College, Oxford.
1889. ‡Bourne, R. H. Fox. 41 Priory-road, Bedford Park, Chiswick.
1866. §BOURNE, STEPHEN, F.S.S. Abberley, Wallington, Surrey.
1890. ‡Bousfield, C. E. 55 Clarendon-road, Leeds.
1884. ‡BOVEY, HENRY T., M.A., Professor of Civil Engineering and Applied Mechanics in McGill University, Montreal. Ontario-avenue, Montreal, Canada.
1888. ‡Bowden, Rev. G. New Kingswood School, Lansdown, Bath.
1870. ‡*Bower, Anthony. Bowersdale, Seaforth, Liverpool.*
1881. *BOWER, F. O., D.Sc., F.R.S., F.L.S., Regius Professor of Botany in the University of Glasgow.
1856. *Bowlby, Miss F. E. 23 Lansdowne-parade, Cheltenham.
1886. ‡Bowlby, Rev. Canon. 101 Newhall-street, Birmingham.
1884. ‡*Bowley, Edwin. Burnt Ash Hill, Lee, Kent.*
1880. ‡Bowly, Christopher. Cirencester.
1887. ‡Bowly, Mrs. Christopher. Cirencester.
1865. §Bowman, F. H., D.Sc., F.R.S.E., F.L.S. Ash Leigh, Ashley Heath, Bowdon, Cheshire.
1887. §Box, Alfred M. 68 Huntingdon-road, Cambridge.
1884. *Boyd, M. A., M.D. 30 Merrion-square, Dublin.
1887. ‡*Boyd, Robert. Manor House, Didsbury, Manchester.*
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, The Very Rev. G. D., M.A., Dean of Salisbury. The Deanery, Salisbury.
1884. *Boyle, R. Vicars, C.S.I. Care of Messrs. Grindlay & Co., 55 Parliament-street, London, S.W.
1892. §BOYS, CHARLES VERNON, F.R.S., Assistant Professor of Physics in the Royal College of Science, London, S.W.
1872. *BRABROOK, E. W., F.S.A. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Bushey Lodge, Teddington, Middlesex.
1893. §Bradley, F. L. Bel Air, Alderley Edge, Cheshire.
1892. §Bradshaw, W. Carisbrooke House, The Park, Nottingham.
1857. *Brady, Cheyne, M.R.I.A. Trinity Vicarage, West Bromwich.
1863. ‡BRADY, GEORGE S., M.D., LL.D., F.R.S., F.L.S., Professor of Natural History in the Durham College of Science, Newcastle-on-Tyne. 2 Mowbray-villas, Sunderland.
1880. *Brady, Rev. Nicholas, M.A. Rainham Hall, Rainham, Romford, Essex.
1864. ‡BRAHAM, PHILIP, F.C.S. 6 George-street, Bath.
1870. ‡Braidwood, Dr. 35 Park-road South, Birkenhead.
1888. §Braikenridge, W. J., J.P. 16 Royal-crescent, Bath.
1879. ‡Bramley, Herbert. 6 Paradise-square, Sheffield.
1865. §BRAMWELL, Sir FREDERICK J., Bart., D.C.L., LL.D., F.R.S., M.Inst.C.E. 5 Great George-street, London, S.W.
1872. ‡Bramwell, William J. 17 Prince Albert-street, Brighton.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. 1 Cintra-terrace, Hill's-road, Cambridge.

Year of Election.

1885. *Bratby, William, J.P. Oakfield Hale, Altrincham, Cheshire.
1890. *Bray, George. Belmont, Headingley, Leeds.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1877. ‡Brent, Francis. 19 Clarendon-place, Plymouth.
1882. *Bretherton, C. E. 1 Garden-court, Temple, London, E.C.
1881. *Brett, Alfred Thomas, M.D. Watford House, Watford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1875. ‡*Briant, T. Hampton Wick, Kingston-on-Thames.*
1886. §Bridge, T. W., M.A., Professor of Zoology in the Mason Science College, Birmingham.
1870. *Bridson, Joseph R. Sawrey, Windermere.
1887. ‡Brierley, John, J.P. The Clough, Whitefield, Manchester.
1870. ‡Brierley, Joseph. New Market-street, Blackburn.
1886. ‡Brierley, Leonard. Somerset-road, Edgbaston, Birmingham.
1879. ‡Brierley, Morgan. Denshaw House, Saddleworth.
1870. *Brigg, John. Broomfield, Keighley, Yorkshire.
1889. ‡*Brigg, T. H. The Grange, Weston, near Otley, Yorkshire.*
1890. ‡Brigg, W. A. Kildwick Hall, near Keighley, Yorkshire.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
1893. §Bright, Joseph. Western-terrace, The Park, Nottingham.
1868. ‡Brine, Admiral Lindesay, F.R.G.S. United Service Club, Pall Mall, London, S.W.
1893. §Briscoe, Albert E., A.R.C.Sc., B.Sc. University College, Nottingham.
1884. ‡Brisette, M. H. 424 St. Paul-street, Montreal, Canada.
1879. ‡Brittain, Frederick. Taptonville-crescent, Sheffield.
1879. *Brittain, W. H., J.P. Storth Oaks, Ranmoor, Sheffield.
1878. ‡Britten, James, F.L.S. Department of Botany, British Museum, London, S.W.
1884. *Brittle, John R., M.Inst.C.E., F.R.S.E. Farad Villa, Vanbrugh Hill, Blackheath, London, S.E.
1859. *Brodhurst, Bernard Edward, F.R.C.S. 20 Grosvenor-street, Grosvenor-square, London, W.
1883. *Brodie, David, M.D. 12 Patten-road, Wandsworth Common, S.W.
1865. ‡Brodie, Rev. Peter Bellinger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1884. ‡Brodie, William, M.D. 64 Lafayette-avenue, Detroit, Michigan, U.S.A.
1883. *Brodie-Hall, Miss W. L. The Gore, Eastbourne.
1881. §Brook, Robert G. Rowen-street, St. Helens, Lancashire.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Ven. Archdeacon J. Ingham. The Vicarage, Halifax.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1888. ‡Brooke, Rev. Canon R. E., M.A. 14 Marlborough-buildings, Bath.
1887. §Brooks, James Howard. Elm Hirst, Wilmslow, near Manchester.
1863. ‡Brooks, John Crosse. 14 Lovaine-place, Newcastle-on-Tyne.
1887. ‡Brooks, S. H. Slade House, Levenshulme, Manchester.
1887. *Bros, W. Law. Sidcup, Kent.
1883. §Brotherton, E. A. Fern Cliffe, Ilkley, Yorkshire.
1886. §Brough, Professor Joseph, LL.M., Professor of Logic and Philosophy in University College, Aberystwith.
1885. *Browett, Alfred. 14 Dean-street, Birmingham.
1863. *Brown, Alexander Crum, M.D., LL.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinburgh. 8 Belgrave-crescent, Edinburgh.

Year of Election.

1892. ‡Brown, Andrew, M.Inst.C.E. Messrs. Wm. Simons & Co., Renfrew, near Glasgow.
1893. §Brown, Arthur, M.Inst.C.E. 6 Vickers-street, Nottingham.
1867. ‡Brown, Charles Gage, M.D., C.M.G. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 192 Hope-street, Glasgow.
1871. ‡Brown, David. Willowbrae House, Midlothian.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1883. ‡Brown, Mrs. Ellen F. Campbell. 27 Abercromby-square, Liverpool.
1881. ‡Brown, Frederick D. 26 St. Giles's-street, Oxford.
1883. ‡Brown, George Dransfield. Henley Villa, Ealing, Middlesex, W.
1884. ‡Brown, Gerald Culmer. Lachute, Quebec, Canada.
1883. ‡Brown, Mrs. H. Bienz. 26 Ferryhill-place, Aberdeen.
1884. ‡Brown, Harry. University College, London, W.C.
1883. ‡Brown, Mrs. Helen. 52 Grange Loan, Edinburgh.
1870. §BROWN, HORACE T., F.R.S., F.C.S. 47 High-street, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1883. ‡Brown, Miss Isabella Spring. 52 Grange Loan, Edinburgh.
1870. *BROWN, Professor J. CAMPBELL, D.Sc., F.C.S. University College, Liverpool.
1876. §Brown, John. Edenderry House, Newtownbreda, Belfast.
1881. *Brown, John, M.D. 68 Bank-parade, Burnley, Lancashire.
1882. *Brown, John. 7 Second-avenue, Sherwood Rise, Nottingham.
1859. ‡Brown, Rev. John Crombie, LL.D. Haddington, N.B.
1882. *Brown, Mrs. Mary. 68 Bank-parade, Burnley, Lancashire.
1886. §Brown R., R.N. Laurel Bank, Barnhill, Perth.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-upon-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.L.S., F.R.G.S. Fersley, Rydal-road, Streatham, London, S.W.
1868. ‡Brown, Samuel, M.Inst.C.E., Government Engineer. Nicosia, Cyprus.
1891. §BROWN, T. FORSTER, M.Inst.C.E. Guildhall Chambers, Cardiff.
1865. ‡Brown, William. 41A New-street, Birmingham.
1885. ‡Brown, W. A. The Court House, Aberdeen.
1884. ‡Brown, William George. Ivy, Albemarle Co., Virginia, U.S.A.
1863. ‡Browne, Sir Benjamin Chapman, M.Inst.C.E. Westacres, Newcastle-upon-Tyne.
1892. ‡Browne, Harold Crichton. Crindon, Dumfries.
1879. ‡Browne, Sir J. Crichton, M.D., LL.D., F.R.S., F.R.S.E. 61 Carlisle-street-mansions, Victoria-street, London, S.W.
1891. §Browne, Montagu, F.G.S. Town Museum, Leicester.
1862. *Browne, Robert Clayton, M.A. Sandbrook, Tullow, Co. Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Redcot, Bradbourne, Sevenoaks, Kent.
1865. *Browne, William, M.D. Heath Wood, Leighton Buzzard.
1887. ‡Brownell, T. W. 6 St. James's-square, Manchester.
1865. ‡Browning, John, F.R.A.S. 63 Strand, London, W.C.
1883. ‡Browning, Oscar, M.A. King's College, Cambridge.
1855. ‡Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1892. ‡Bruce, James. 10 Hill-street, Edinburgh.
1893. §Bruce, William S. University Hall, Edinburgh.
1863. *Brunel, H. M., M.Inst.C.E. 21 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 21 Delahay-street, Westminster, S.W.
1875. ‡Brunlees, John. 5 Victoria-street, Westminster, S.W.
1868. ‡BRUNTON, T. LAUDER, M.D., D.Sc., F.R.S. 10 Stratford-place, Oxford-street, London, W.
1891. ‡*Bruton, Edward Henry.* 181 *Richmond-road, Cardiff.*
1878. §Brutton, Joseph. Yeovil.

Year of Election.

1886. *BRYAN, G. H. Thornlea, Trumpington-road, Cambridge.
1884. ‡Bryce, Rev. Professor George. The College, Manitoba, Canada.
1890. §Bubb, Henry. Ullenwood, near Cheltenham.
1871. §BUCHAN, ALEXANDER, M.A., LL.D., F.R.S.E., Sec. Scottish Meteorological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
1885. *Buchan, William Paton. Fairyknowe, Cambuslang, N.B.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. 12 Barnard-road, Birkenhead, Cheshire.
1881. *Buchanan, John H., M.D. Sowerby, Thirsk.
1871. ‡BUCHANAN, JOHN YOUNG, M.A., F.R.S., F.R.S.E., F.R.G.S., F.C.S. 10 Moray-place, Edinburgh.
1884. ‡Buchanan, W. Frederick. Winnipeg, Canada.
1883. ‡Buckland, Miss A. W. 108 Portsdown-road, London, W.
1886. *Buckle, Edmund W. 23 Bedford-row, London, W.C.
1864. ‡BUCKLE, Rev. GEORGE, M.A. Wells, Somerset.
1865. *Buckley, Henry. 8 St. Mary's-road, Leamington.
1886. §Buckley, Samuel. Merlewood, Beaver-park, Didsbury.
1884. *Buckmaster, Charles Alexander, M.A., F.C.S. 16 Heathfield-road, Mill Hill Park, London, W.
1880. ‡Buckney, Thomas, F.R.A.S. 53 Gower-street, London, W.C.
1869. ‡Bucknill, J. C., M.D., F.R.S. East Cliff House, Bournemouth.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1887. ‡Budenberg, C. F., B.Sc. Buckau Villa, Demesne-road, Whalley Range, Manchester.
1875. ‡Budgett, Samuel. Kirton, Albemarle-road, Beckenham, Kent.
1883. ‡Buick, Rev. George R., M.A. Cullybackey, Co. Antrim, Ireland.
1893. §Bulleid, Arthur. Glastonbury.
1871. ‡Bulloch, Matthew. 48 Prince's-gate, London, S.W.
1881. ‡Bulmer, T. P. Mount-villas, York.
1883. ‡Bulpit, Rev. F. W. Crossens Rectory, Southport.
1865. ‡Bunce, John Thackray. 'Journal' Office, New-street, Birmingham.
1886. §Burbury, S. H., M.A., F.R.S. 1 New-square, Lincoln's Inn, London, W.C.
1842. *Burd, John. Glen Lodge, Knocknerea, Sligo.
1875. ‡Burder, John, M.D. 7 South-parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. 1 Stratton-street, Piccadilly, London, W.
1881. ‡Burdett-Coutts, W. L. A. B., M.P. 1 Stratton-street, Piccadilly, London, W.
1891. ‡Burge, Very Rev. T. A. Ampleforth Cottage, near York.
1884. *Burland, Jeffrey H. 287 University-street, Montreal, Canada.
1888. ‡Burne, H. Holland. 28 Marlborough-buildings, Bath.
1883. *Burne, Major-General Sir Owen Tudor, K.C.S.I., C.I.E., F.R.G.S. 132 Sutherland-gardens, Maida Vale, London, W.
1876. ‡Burnet, John. 14 Victoria-crescent, Dowanhill, Glasgow.
1885. *Burnett, W. Kendall, M.A. 11 Belmont-street, Aberdeen.
1877. ‡Burns, David. Alston, Carlisle.
1884. ‡Burns, Professor James Austin. Southern Medical College, Atlanta, Georgia, U.S.A.
1883. ‡Burr, Percy J. 20 Little Britain, London, E.C.
1887. †Burroughs, Eggleston, M.D. Snow Hill-buildings, London, E.C.
1881. §Burroughs, S. M. Snow Hill-buildings, London, E.C.
1883. *Burrows, Abraham. Greenhall, Atherton, near Manchester.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1891. †Burt, J. J. 103 Roath-road, Cardiff.
1888. ‡Burt, John Mowlem. 3 St. John's-gardens, Kensington, London, W.

Year of Election.

1888. ‡Burt, Mrs. 3 St. John's-gardens, Kensington, London, W.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1889. ‡Burton, Rev. R. Lingen. Little Aston Sutton, Coldfield.
1892. ‡Burton-Brown, Colonel Alexander, R.A., F.R.A.S., F.G.S. St. George's Club, Hanover-square, London, W.
1887. *Bury, Henry. Trinity College, Cambridge.
1878. ‡BUTCHER, J. G., M.A. 22 Collingham-place, London, S.W.
1884. *Butcher, William Deane, M.R.C.S.Eng. Clydesdale, Windsor.
1884. ‡Butler, Matthew I. Napanee, Ontario, Canada.
1888. ‡Buttanshaw, Rev. John. 22 St. James's-square, Bath.
1884. *Butterworth, W. Greenhill, Church-lane, Harpurhey, Manchester.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1883. ‡Buxton, Miss F. M. Newnham College, Cambridge.
1887. *Buxton, J. H. Poste Restante, Melbourne, Australia.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1881. ‡Buxton, Sydney. 15 Eaton-place, London, S.W.
1883. ‡Buxton, Rev. Thomas, M.A. 19 Westcliffe-road, Birkdale, Southport.
1872. ‡Buxton, Sir Thomas Fowell, Bart., F.R.G.S. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. 22 Dingle-lane, Toxteth-park, Liverpool.
1885. ‡Byres, David. 63 North Bradford, Aberdeen.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1883. ‡Byrom, John R. Mere Bank, Fairfield, near Manchester.
1875. ‡Byrom, W. Ascroft, F.G.S. 31 King-street, Wigan.

1889. ‡Cackett, James Thoburn. 60 Larkspur-terrace, Newcastle-upon-Tyne.
1892. ‡Cadell, Henry M., B.Sc., F.R.S.E. Grange, Bo'ness, N.B.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1876. ‡*Caird, Edward B. 8 Scotland-street, Glasgow.*
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1875. ‡Caldicott, Rev. J. W., D.D. The Rectory, Shipston-on-Stour.
1886. *Caldwell, William Hay. Birnam, Chaucer-road, Cambridge.
1868. ‡Caley, A. J. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1887. ‡CALLAWAY CHARLES, M.A., D.Sc., F.G.S. Sandon, Wellington, Shropshire.
1892. §Calvert, A. F., F.R.G.S. The Mount, Oseney-crescent, Camden-road, London, N.
1884. ‡Cameron, Æneas. Yarmouth, Nova Scotia, Canada.
1876. ‡Cameron, Sir Charles, Bart., M.D., LL.D., M.P. 1 Huntly-gardens, Glasgow.
1857. ‡CAMERON, Sir CHARLES A., M.D. 15 Pembroke-road, Dublin.
1884. ‡Cameron, James C., M.D. 41 Belmont-park, Montreal, Canada.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1884. ‡Campbell, Archibald H. Toronto, Canada.
1883. ‡*Campbell, H. J. 81 Kirkstall-road, Talfourd Park, Streatham Hill, London, S.W.*
1876. ‡Campbell, James A., LL.D., M.P. Stracathro House, Brechin.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1862. *CAMPION, Rev. WILLIAM M., D.D. Queen's College, Cambridge.
1882. ‡Candy, F. H. 71 High-street, Southampton.
1890. ‡Cannan, Edwin, M.A., F.S.S. 24 St. Giles's, Oxford.
1888. ‡Cappel, Sir Albert J. L., K.C.I.E. 27 Kensington Court-gardens, London, W.

Year of Election.

1880. ‡Capper, Robert. 18 Parliament-street, Westminster, S.W.
1883. ‡Capper, Mrs. R. 18 Parliament-street, Westminster, S.W.
1887. ‡Capstick, John Walton. University College, Dundee.
1873. *CARBUTT, Sir EDWARD HAMER, Bart., M.Inst.C.E. 19 Hyde Park-gardens, London, W.
1877. ‡Carkeet, John. 3 St. Andrew's-place, Plymouth.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡*Carmichael, George. 11 Dudhope-terrace, Dundee.*
1876. ‡Carmichael, Neil, M.D. 22 South Cumberland-street, Glasgow.
1884. ‡Carnegie, John. Peterborough, Ontario, Canada.
1884. ‡Carpenter, Louis G. Agricultural College, Fort Collins, Colorado, U.S.A.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1884. *Carpmael, Charles. Toronto, Canada.
1889. ‡Carr, Cuthbert Ellison. Hedgeley, Alnwick.
1893. §Carr, J. Wesley. 128 Mansfield-road, Nottingham.
1889. ‡Carr-Ellison, John Ralph. Hedgeley, Alnwick.
1867. ‡CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, S.W.
1886. ‡CARSLAKE, J. BARHAM. 30 Westfield-road, Birmingham.
1883. ‡Carson, John. 51 Royal Avenue, Belfast.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1868. ‡Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 78 Rodney-street, Liverpool.
1883. ‡Carter, W. C. Manchester and Salford Bank, Southport.
1883. ‡Carter, Mrs. Manchester and Salford Bank, Southport.
1878. *Cartwright, Ernest H., M.A., M.B. 1 Courtfield-gardens, London, S.W.
1870. §Cartwright, Joshua, M.Inst.C.E., Borough Surveyor. Bury, Lancashire.
1862. ‡Carulla, F. J. R. 84 Argyll-terrace, Derby.
1884. *Carver, Rev. Canon Alfred J., D.D., F.R.G.S. Lynnhurst, Streatham Common, London, S.W.
1884. ‡Carver, Mrs. Lynnhurst, Streatham Common, London, S.W.
1883. ‡Carver, James. Garfield House, Elm-avenue, Nottingham.
1887. ‡Casartelli, Rev. L. C., M.A., Ph.D. St. Bede's College, Manchester.
1866. ‡Casella, L. P., F.R.A.S. The Lawns, Highgate, London, N.
1871. ‡Cash, Joseph. Bird-grove, Coventry.
1873. *Cash, William, F.G.S. 38 Elmfield-terrace, Savile Park, Halifax.
1888. ‡Cater, R. B. Avondale, Henrietta Park, Bath.
1874. ‡Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. Lea Hall, Gateacre, Liverpool.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1886. *Cave-Moyles, Mrs. Isabella. Repton Lodge, Harborne, Birmingham.
1886. ‡*Cay, Albert. Ashleigh, Westbourne-road, Birmingham.*
1860. §CAYLEY, ARTHUR, M.A., D.C.L., LL.D., D.Sc., F.R.S., V.P.R.A.S., Sadlerian Professor of Pure Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1860. ‡CHADWICK, DAVID. The Poplars, Herne Hill, London, S.E.
1883. ‡Chadwick, James Percy. 51 Alexandra-road, Southport.
1859. ‡Chadwick, Robert. Highbank, Manchester.

Year of Election.

1883. ‡Chalk, William. 24 Gloucester-road, Birkdale, Southport.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1883. ‡Chamberlain, George, J.P. Helensholme, Birkdale Park, Southport.
1884. ‡Chamberlain, Montague. St. John, New Brunswick, Canada.
1883. ‡CHAMBERS, CHARLES, F.R.S. Colába Observatory, Bombay.
1883. ‡Chambers, Mrs. Colába Observatory, Bombay.
1883. ‡Chambers, Charles, jun., Assoc.M.Inst.C.E. Colába Observatory, Bombay.
1868. ‡*Chambers, W. O. Lowestoft, Suffolk.*
*Champney, Henry Nelson. 4 New-street, York.
1881. *Champney, John E. Woodlands, Halifax.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. 51 Prince's-gate, London, S.W.
1886. *Chance, John Horner. 40 Augustus-road, Edgbaston, Birmingham.
1865. ‡Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1888. ‡Chandler, S. Whitty, B.A. Sherborne, Dorset.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Hill End, Mottram, Manchester.
1889. ‡Chapman, L. H. 147 Park-road, Newcastle-upon-Tyne.
1884. ‡Chapman, Professor. University College, Toronto, Canada.
1877. ‡Chapman, T. Algernon, M.D. Firbank, Hereford.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. 30 Milman-street, Bedford-row, London, W.C.
1886. ‡Chate, Robert W. Southfield, Edgbaston, Birmingham.
1883. ‡Chater, Rev. John. Part-street, Southport.
1884. *Chatterton, George, M.A., M.Inst.C.E. 46 Queen Anne's-gate, London, S.W.
1886. §Chattock, A.P. University College, Bristol.
1867. *Chatwood, Samuel, F.R.G.S. High Lawn, Broad Oak Park, Worsley, Manchester.
1884. ‡CHAUVEAU, The Hon. Dr. Montreal, Canada.
1883. ‡Chawner, W., M.A. Emmanuel College, Cambridge.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, S.W.
1887. ‡Cheetham, F. W. Limefield House, Hyde.
1887. ‡Cheetham, John. Limefield House, Hyde.
1874. *Chermside, Lieut.-Colonel H. C., R.E., C.B. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1884. ‡Cherriman, Professor J. B. Ottawa, Canada.
1879. *Chesterman, W. Clarkehouse-road, Sheffield.
CHICHESTER, The Right Rev. RICHARD DURNFORD, D.D., Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Cowley House, Oxford.
1883. ‡Chinery, Edward F. Monmouth House, Lymington.
1884. ‡Chipman, W. W. L. 6 Place d'Armes, Ontario, Canada.
1889. ‡Chirney, J. W. Morpeth.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. The Rectory, Beaconsfield R.S.O., Bucks.
1882. ‡Chorley, George. Midhurst, Sussex.
1887. ‡Chorlton, J. Clayton. New Holme, Withington, Manchester.
1893. *Chree, Charles. Kew Observatory, Richmond, Surrey.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
1884. *Christie, William. 29 Queen's Park, Toronto, Canada.
1875. *Christopher, George, F.C.S. 6 Barrow-road, Streatham Common, London, S.W.

Year of Election.

1876. *CHRYSTAL, GEORGE, M.A., LL.D., F.R.S.E., Professor of Mathematics in the University of Edinburgh. 5 Belgrave-crescent, Edinburgh.
1870. §CHURCH, A. H., M.A., F.R.S., F.C.S., Professor of Chemistry to the Royal Academy of Arts, London. Shelsley, Ennerdale-road, Kew, Surrey.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857. ‡Churchill, F., M.D. Ardtrea Rectory, Stewartstown, Co. Tyrone.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
1876. ‡Clark, David R., M.A. 31 Waterloo-street, Glasgow.
1890. ‡Clark, E. K. 81 Caledonian-road, Leeds.
1877. *Clark, F. J. Street, Somerset.
Clark, George T. 44 Berkeley-square, London, W.
1876. ‡Clark, George W. 31 Waterloo-street, Glasgow.
1892. §Clark, James, M.A., Ph.D. Yorkshire College, Leeds.
1892. ‡Clark, James. Chapel House, Paisley.
1876. ‡Clark, Dr. John. 138 Bath-street, Glasgow.
1881. ‡Clark, J. Edmund, B.A., B.Sc., F.G.S. 12 Feversham-terrace, York.
1861. ‡Clark, Latimer, F.R.S., M.Inst.C.E. 11 Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1883. ‡Clarke, Rev. Canon, D.D. 59 Hoghton-street, Southport.
1887. §Clarke, C. Goddard. Ingleside, Elm-grove, Peckham, S.E.
1875. ‡Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
1886. ‡Clarke, David. Langley-road, Small Heath, Birmingham.
1886. §Clarke, Rev. H. J. Great Barr Vicarage, Birmingham.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1875. ‡CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1861. **Clarke, John Hope. 62 Nelson-street, Chorlton-on-Medlock, Manchester.*
1877. ‡Clarke, Professor John W. University of Chicago, Illinois, U.S.A.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1883. ‡Clarke, W. P., J.P. 15 Hesketh-street, Southport.
1884. ‡Claxton, T. James. 461 St. Urbain-street, Montreal, Canada.
1889. §CLAYDEN, A. W., M.A., F.G.S. St. John's, Polsloe-road, Exeter.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1890. *Clayton, William Wikely. Gipton Lodge, Leeds.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S. Stravithie, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1875. ‡Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1861. §CLELAND, JOHN, M.D., D.Sc., F.R.S., Professor of Anatomy in the University of Glasgow. 2 College, Glasgow.
1886. ‡Clifford, Arthur. Beechcroft, Edgbaston, Birmingham.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. 3 Bardwell-road, Banbury-road, Oxford.
1893. §Clofford, William. 36 Mansfield-road, Nottingham.
Clonbrock, Lord Robert. Clonbrock, Galway.
1878. §Close, Rev. Maxwell H., F.G.S. 40 Lower Baggot-street, Dublin.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1892. ‡Clouston, T. S., M.D. Tipperlinn House, Edinburgh.
1883. *CLOWES, FRANK, D.Sc., F.C.S., Professor of Chemistry in University College, Nottingham. 99 Waterloo-crescent, Nottingham.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.

Year of Election.

1881. *Clutton, William James. The Mount, York.
1885. ‡Clyne James. Rubislaw Den South, Aberdeen.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1891. *Coates, Henry. Pitcullen House, Perth.
Cobb, Edward. Falkland House, St. Ann's, Lewes.
1884. §Cobb, John. Summerhill, Apperley Bridge, Leeds.
1889. ‡Cochrane, Cecil A. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1889. ‡Cochrane, William. Oakfield House, Gosforth, Newcastle-upon-Tyne.
1892. ‡Cockburn, John. Glencorse House, Milton Bridge, Edinburgh.
1883. ‡Cockshott, J. J. 24 Queen's-road, Southport.
1861. *Coe, Rev. Charles C., F.R.G.S. Fairfield, Heaton, Bolton.
1881. *COFFIN, WALTER HARRIS, F.C.S. 94 Cornwall-gardens, South Kensington, London, S.W.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1884. *Cohen, B. L., M.P. 30 Hyde Park-gardens, London, W.
1887. ‡Cohen, Julius B. Yorkshire College, Leeds.
1887. ‡Cohen, Sigismund. 111 Portland-street, Manchester.
1853. ‡Colchester, William, F.G.S. Burwell, Cambridge.
1868. ‡*Colchester, W. P. Bassingbourn, Royston.*
1893. §Cole, Grenville, A. J., F.G.S. Royal College of Science, Dublin.
1879. ‡Cole, Skelton. 387 Glossop-road, Sheffield.
1893. §Coleman, J. B., F.C.S., A.R.C.S. University College, Nottingham.
1878. ‡Coles, John, Curator of the Map Collection R.G.S. 1 Savile-row, London, W.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1892. §Collet, Miss Clara E. 7 Coleridge-road, London, N.
1892. §Collie, Alexander. Harlaw House, Inverurie.
1887. ‡Collie, Norman. University College, Gower-street, London, W.C.
1887. ‡Collier, Thomas. Ashfield, Alderley Edge, Manchester.
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1893. §Collinge, Walter E. Mason College, Birmingham.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 69 Great Russell-street, London, W.C.
1861. *Collingwood, J. Frederick, F.G.S. 96 Great Portland-street, London, W.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
1876. ‡COLLINS, J. H., F.G.S. 60 Heber-road, Dulwich Rise, London, S.E
1876. ‡Collins, Sir William. 3 Park-terrace East, Glasgow.
1892. ‡Colman, H. G. Mason College, Birmingham.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1882. ‡Colmer, Joseph G., C.M.G. Office of the High Commissioner for Canada, 9 Victoria-chambers, London, S.W.
1884. ‡Colomb, Sir J. C. R., F.R.G.S. Dromquinna, Kenmare, Kerry, Ireland; and Junior United Service Club, London, S.W.
1893. §Coltman, Thomas. West End Cottage, King Richard's-road, Leicester.
1888. ‡Commans, R. D. Macaulay-buildings, Bath.
1884. ‡Common, A. A., LL.D., F.R.S., F.R.A.S. 63 Eaton-rise, Ealing, Middlesex, W.
1891. ‡Common, J. F. F. 3 Glossop-terrace, Cardiff.
1892. §Comyns, Frank, B.A., F.C.S. The Grammar School, Durham.
1884. ‡Conklin, Dr. William A. Central Park, New York, U.S.A.
1852. ‡Connal, Sir Michael. 16 Lynedoch-terrace, Glasgow.
1890. ‡Connon, J. W. Park-row, Leeds.
1871. *Connor, Charles C., M.P. Notting Hill House, Belfast.
1881. ‡CONROY, Sir JOHN, Bart., M.A., F.R.S. Balliol College, Oxford.

Year of Election.

1893. §Conway, W. M., M.A. 21 Clanricarde-gardens, London, W.
1876. ‡Cook, James. 162 North-street, Glasgow.
1882. ‡Cooke, Major-General A. C., R.E., C.B., F.R.G.S. Palace-chambers, Ryder-street, London, S.W.
1876. *Cooke, Conrad W. 28 Victoria-street, London, S.W.
1881. ‡Cooke, F. Bishopshill, York.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1868. ‡Cooke, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
1884. ‡Cooke, R. P. Brockville, Ontario, Canada.
1878. ‡Cooke, Samuel, M.A., F.G.S. Poona, Bombay.
1881. ‡Cooke, Thomas. Bishopshill, York.
1859. *Cooke, His Honour Judge, M.A., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1883. ‡Cooke-Taylor, R. Whateley. Frenchwood House, Preston.
1883. ‡Cooke-Taylor, Mrs. Frenchwood House, Preston.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1888. ‡Cooley, George Parkin. Cavendish Hill, Sherwood, Nottingham.
1883. ‡*Coomer, John. Willaston, near Nantwich.*
1884. ‡Coon, John S. 604 Main-street, Cambridge Pt., Massachusetts, U.S.A.
1893. §Cooper, F. W. 14 Hamilton-road, Sherwood Rise, Nottingham.
1883. ‡Cooper, George B. 67 Great Russell-street, London, W.C.
1838. Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1884. ‡Cooper, Mrs. M. A. West Tower, Marple, Cheshire.
1889. ‡Coote, Arthur. The Minories, Jesmond, Newcastle-upon-Tyne.
1884. ‡Cope, E. D. Philadelphia, U.S.A.
1878. ‡Cope, Rev. S. W. Bramley, Leeds.
1871. ‡Copeland, Ralph, Ph.D., F.R.A.S., Astronomer Royal for Scotland and Professor of Astronomy in the University of Edinburgh.
1885. ‡Copland, W., M.A. Tortorston, Peterhead, N.B.
1881. ‡Copperthwaite, H. Holgate Villa, Holgate-lane, York.
1842. Corbett, Edward. Grange-avenue, Levenshulme, Manchester.
1891. §Corbett, E. W. M. Y Fron, Pwllypant, Cardiff.
1887. *Corcoran, Bryan. 31 Mark-lane, London, E.C.
1881. §Cordeaux, John. Great Cotes House, R.S.O., Lincoln.
1883. *Core, Thomas H. Fallowfield, Manchester.
1870. *Corfield, W. H., M.A., M.D., F.C.S., F.G.S., Professor of Hygiene and Public Health in University College. 19 Savile-row, London, W.
1893. *Corner, Samuel, B.A., B.Sc. 95 Forest-road West, Nottingham.
1889. ‡Cornish, Vaughan. Ivy Cottage, Newcastle, Staffordshire.
1884. *Cornwallis, F. S. W. Linton Park, Maidstone.
1885. ‡Corry, John. Rosenheim, Parkhill-road, Croydon.
1888. ‡Corser, Rev. Richard K. 12 Beaufort-buildings East, Bath.
1891. ‡Cory, John, J.P. Vaindre Hall, near Cardiff.
1891. ‡Cory, Alderman Richard, J.P. Oscar House, Newport-road, Cardiff.
1883. ‡Costelloe, B. F. C., M.A., B.Sc. 33 Chancery-lane, London, W.C.
1891. *Cotsworth, Haldane Gwilt. Sand Park, Shaldon, Devonshire.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. King-street, Manchester.
1874. *Cotterill, J. H., M.A., F.R.S., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. ‡Cotton, General Frederick C., R.E., C.S.I. 13 Longridge-road, Earl's Court-road, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.

Year of Election.

1879. ‡Cottrill, Gilbert I. Shepton Mallet, Somerset.
1876. ‡Couper, James. City Glass Works, Glasgow.
1876. ‡Couper, James, jun. City Glass Works, Glasgow.
1889. ‡Courtney, F. S. 77 Redcliffe-square, South Kensington, London, S.W.
1890. ‡Cousins, John James. Allerton Park, Chapel Allerton, Leeds.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William, F.L.S., F.G.S. 31 Belsize Park-gardens, London, N.W.
1886. ‡Cowen, Mrs. G. R. 9 The Ropewalk, Nottingham.
Cowie, The Very Rev. Benjamin Morgan, M.A., D.D., Dean of Exeter. The Deanery, Exeter.
1871. ‡Cowper, C. E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. Lyndhurst, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1892. ‡Cox, Robert. 34 Drumsheugh-gardens, Edinburgh.
1882. ‡Cox, Thomas A., District Engineer of the S., P., and D. Railway. Lahore, Punjab. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1888. ‡Cox, Thomas W. B. The Chestnuts, Lansdowne, Bath.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1883. §Crabtree, William, M.Inst.C.E. 126 Manchester-road, Southport.
1890. ‡Cradock, George. Wakefield.
1892. *Craig, George A. 66 Edge-lane, Liverpool.
1884. §Craigie, Major P. G., F.S.S. 6 Lyndhurst-road, Hampstead, London, N.W.
1876. ‡Cramb, John. Larch Villa, Helensburgh, N.B.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1884. ‡Crathern, James. Sherbrooke-street, Montreal, Canada.
1887. §Craven, John. Smedley Lodge, Cheetham, Manchester.
1887. *Craven, Thomas, J.P. Woodheyes Park, Ashton-upon-Mersey, Cheshire.
1871. *Crawford, William Caldwell, M.A. 1 Lockharton-gardens, Slateford, Edinburgh.
1871. *Crawford and Balcarres, The Right Hon. the Earl of, K.T., LL.D., F.R.S., F.R.A.S. Dun Echt, Aberdeen.
1846. *Crawshaw, The Right Hon. Lord. Whatton, Loughborough, Leicestershire.
1890. §Crawshaw, Charles B. Rufford Lodge, Dewsbury.
1883. *Crawshaw, Edward, F.R.G.S. 25 Tollington-park, London, N.
1870. *Crawshay, Mrs. Robert. Cathedine, Bwlch, Breconshire.
1885. §Creak, Captain E. W., R.N., F.R.S. 36 Kidbrooke Park-road, Blackheath, London, S.E.
1879. ‡Creswick, Nathaniel. Chantry Grange, near Sheffield.
1876. *Crewdson, Rev. George. St. Mary's Vicarage, Windermere.
1887. *Crewdson, Theodore. Norcliffe Hall, Handforth, Manchester.
1880. *Crisp, Frank, B.A., LL.B., F.L.S. 5 Lansdowne-road, Notting Hill, London, W.
1890. *Croft, W. B., M.A. Winchester College, Hampshire.
1878. ‡Croke, John O'Byrne, M.A. University College, Stephen's Green, Dublin.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1885. ‡Crombie, Charles W. 41 Carden-place, Aberdeen.
1885. ‡Crombie, John. 129 Union-street, Aberdeen.

Year of Election.

1885. ‡Crombie, John, jun. Daveston, Aberdeen.
1885. ‡CROMBIE, J. W., M.A., M.P. Balgownie Lodge, Aberdeen.
1885. ‡Crombie, Theodore. 18 Albyn-place, Aberdeen.
1887. ‡Crompton, A. 1 St. James's-square, Manchester.
1886. ‡Crompton, Dickinson W. 40 Harborne-road, Edgbaston, Birmingham.
1887. §CROOK, HENRY T. 9 Albert-square, Manchester.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 7 Kensington Park-gardens, London, W.
1879. ‡Crookes, Mrs. 7 Kensington Park-gardens, London, W.
1870. ‡Crosfield, C. J. Gledhill, Sefton Park, Liverpool.
1870. *Crosfield, William, M.P. Annesley, Aigburth, Liverpool.
1890. ‡Cross, E. Richard, LL.B. Harwood House, New Parks-crescent, Scarborough.
1887. §Cross, John. Beaucliffe, Alderley Edge, Cheshire.
1861. ‡Cross, Rev. John Edward, M.A. Halecote, Grange-over-Sands.
1883. ‡Cross, Rev. Prebendary, LL.B. Part-street, Southport.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1886. ‡Crosskey, Cecil. 117 Gough-road, Birmingham.
1853. ‡Crosskill, William. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bemerside, Halifax.
1871. ‡*Crossley, Herbert. Ferney Green, Bowness, Ambleside.*
1887. *Crossley, William J. Glenfield, Bowdon, Cheshire.
1883. ‡Crowder, Robert. Stanwix, Carlisle.
1882. §Crowley, Frederick. Ashdell, Alton, Hampshire.
1890. *Crowley, Ralph Henry. Bramley Oaks, Croydon.
1883. ‡*Crowther, Elon. Cambridge-road, Huddersfield.*
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-upon-Tyne.
1885. ‡Cruickshank, Alexander, LL.D. 20 Rose-street, Aberdeen.
1888. ‡Crummack, William J. London and Brazilian Bank, Rio de Janeiro, Brazil.
1873. ‡Crust, Walter. Hall-street, Spalding.
1883. *Cryer, Major J. H. The Grove, Manchester-road, Southport.
Culley, Robert. Bank of Ireland, Dublin.
1883. *Culverwell, Edward P. 40 Trinity College, Dublin.
1878. ‡Culverwell, Joseph Pope. St. Lawrence Lodge, Sutton, Dublin.
1883. ‡Culverwell, T. J. H. Litfield House, Clifton, Bristol.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Parsonage, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Dunedin, Handforth, Manchester.
1882. *CUNNINGHAM, Lieut.-Colonel ALLAN, R.E., A.I.C.E. 19 Palace Gardens-terrace, Kensington, London, W.
1887. ‡Cunningham, David, M.Inst.C.E., F.R.S.E., F.S.S. Harbour-chambers, Dundee.
1877. *CUNNINGHAM, D. J., M.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in Trinity College, Dublin.
1891. ‡Cunningham, J. H. 4 Magdala-crescent, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1892. ‡Cunningham, Very Rev. John. St. Mary's College, St. Andrews, N.B.
1885. ‡CUNNINGHAM, J. T., B.A. Scottish Marine Station, Granton, Edinburgh.
1869. ‡CUNNINGHAM, ROBERT O., M.D., F.L.S., Professor of Natural History in Queen's College, Belfast.
1883. *CUNNINGHAM, Rev. WILLIAM, D.D., D.Sc. Trinity College, Cambridge.

Year of Election.

1892. ‡*Cunningham, William. 14 Inverleith-gardens, Edinburgh.*
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1892. §Cunningham-Craig, E. H. Clare College, Cambridge.
1885. ‡*Curphey, William S. 15 Bute-mansions, Hill Head, Cardiff.*
1892. *Currie, James, jun. Larkfield, Golden Acre, Edinburgh.
1884. ‡Currier, John McNab. Newport, Vermont, U.S.A.
1878. ‡Curtis, William. Caramore, Sutton, Co. Dublin.
1884. ‡Cushing, Frank Hamilton. Washington, U.S.A.
1883. ‡Cushing, Mrs. M. Croydon, Surrey.
1881. §Cushing, Thomas, F.R.A.S. India Store Depôt, Belvedere-road, Lambeth, London, S.W.

1889. ‡Dagger, John H., F.I.C., F.C.S. Endon, Staffordshire.
1854. ‡Daglish, Robert, M.Inst.C.E. Orrell Cottage, near Wigan.
1883. ‡Dähne, F. W., Consul of the German Empire. 18 Somerset-place, Swansea.
1889. *Dale, Miss Elizabeth. Westbourne, Buxton, Derbyshire.
1887. ‡*Dale, Henry F., F.R.M.S., F.Z.S. Royal London Yacht Club, 2 Savile-row, London, W.*
1863. ‡Dale, J. B. South Shields.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W. Dundee.
1870. ‡Dallinger, Rev. W. H., LL.D., F.R.S., F.L.S. Ingleside, Newstead-road, Lee, London, S.E.
Dalton, Edward, LL.D. Dunkirk House, Nailsworth.
1862. ‡Danby, T. W., M.A., F.G.S. 1 Westbourne-terrace-road, London, W.
1876. ‡Dansken, John. 4 Eldon-terrace, Partickhill, Glasgow.
1849. *Danson, Joseph, F.C.S. Montreal, Canada.
1861. *Darbishire, Robert Dukinfield, B.A., F.G.S. 26 George-street, Manchester.
1876. ‡*Darling, G. Erskine. 247 West George-street, Glasgow.*
1884. ‡Darling, Thomas. 99 Drummond-street, Montreal, Canada.
1882. ‡Darwin, Francis, M.A., M.B., F.R.S., F.L.S. Wychfield, Huntingdon-road, Cambridge.
1881. *Darwin, George Howard, M.A., LL.D., F.R.S., F.R.A.S., Plumian Professor of Astronomy and Experimental Philosophy in the University of Cambridge. Newnham Grange, Cambridge.
1878. *Darwin, Horace. The Orchard, Huntingdon-road, Cambridge.
1882. ‡Darwin, W. E., F.G.S. Bassett, Southampton.
1888. ‡Daubeny, William M. 1 Cavendish-crescent, Bath.
1872. ‡Davenport, John T. 64 Marine-parade, Brighton.
1880. *Davey, Henry, M.Inst.C.E. 3 Prince's-street, Westminster, S.W.
1884. ‡David, A. J., B.A., LL.B. 4 Harcourt-buildings, Temple, London, E.C.
1870. ‡Davidson, Alexander, M.D. 2 Gambier-terrace, Liverpool.
1885. ‡Davidson, Charles B. Roundhay, Fonthill-road, Aberdeen.
1891. ‡Davies, Andrew, M.D. Cefn Parc, Newport, Monmouthshire.
1890. ‡*Davies, Arthur. East Brow Cottage, near Whitby.*
1875. ‡Davies, David. 2 Queen's-square, Bristol.
1887. §Davies, David. 55 Berkley-street, Liverpool.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1887. *Davies, H. Rees. Treborth, Bangor, North Wales.
1893. *Davies, Rev. T. Witton, B.A. Midland Baptist College, Nottingham.

Year of Election.

1842. Davies-Colley, Dr. Thomas. Newton, near Chester.
1887. ‡Davies-Colley, T. C. Hopedene, Kersal, Manchester.
1873. *Davis, Alfred. 28 St. Ermin's-mansions, London, S.W.
1870. *Davis, A. S. St. George's School, Roundhay, near Leeds.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
1842. Davis, Rev. David, B.A. Almswood, Evesham.
1882. ‡Davis, Henry C. Berry Pomeroy, Springfield-road, Brighton.
1883. ‡Davis, Robert Frederick, M.A. Earlsfield, Wandsworth Common, London, S.W.
1885. *Davis, Rudolf. Almswood, Evesham.
1891. ‡Davis, W. 48 Richmond-road, Cardiff.
1886. ‡Davis, W. H. Hazeldean, Pershore-road, Birmingham.
1886. ‡DAVISON, CHARLES, M.A. 373 Gillott-road, Birmingham.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡DAVY, EDMUND W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. R. M. Bedford-circus, Exeter.
1860. *Dawes, John T., F.G.S. Cefn Mawr Hall, Mold, North Wales.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.S.A., F.G.S., Professor of Geology and Palæontology in the Victoria University, Owens College, Manchester. Woodhurst, Fallowfield, Manchester.
1886. ‡Dawson, Bernard. The Laurels, Malvern Link.
1891. ‡Dawson, Edward. 2 Windsor-place, Cardiff.
1885. *Dawson, Major H. P., R.A. East Holt, Alverstoke, Gosport.
1884. ‡Dawson, Samuel. 258 University-street, Montreal, Canada.
1855. §DAWSON, Sir WILLIAM, C.M.G., M.A., LL.D., F.R.S., F.G.S. Montreal, Canada.
1859. *Dawson, Captain William G. The Links, Plumstead Common, Kent.
1892. ‡Day, J. C., F.C.S. 36 Hillside-crescent, Edinburgh.
1870. *DEACON, G. F., M.Inst.C.E. 19 Warwick-square, London, S.W.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1887. ‡Deakin, H. T. Egremont House, Belmont, near Bolton.
1861. ‡Dean, Henry. Colne, Lancashire.
1884. *Debenham, Frank, F.S.S. 26 Upper Hamilton-terrace, London, N.W.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. 1 Obere Sophienstrasse, Cassel, Hessen.
1884. ‡Deck, Arthur, F.C.S. 9 King's-parade, Cambridge.
1893. §Deeley, R. M. 10 Charnwood-street, Derby.
1878. ‡Delany, Rev. William. St. Stanislaus College, Tullamore.
1879. ‡De la Sala, Colonel. Sevilla House, Navarino-road, London, N.W.
1884. *De Laune, C. De L. F. Sharsted Court, Sittingbourne.
1889. ‡Dendy, Frederick Walter. 3 Mardale-parade, Gateshead.
1873. ‡Denham, Thomas, J.P. Huddersfield.
1884. ‡*Denman, Thomas W. Lamb's-buildings, Temple, London, E.C.*
1889. §DENNY, ALFRED, F.L.S., Professor of Biology in the Firth College, Sheffield.
Dent, William Yerbury. Royal Arsenal, Woolwich.
1874. §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.
1874. *Derham, Walter, M.A., LL.M., F.G.S. 76 Lancaster-gate, London, W.
1878. ‡De Rinzy, James Harward. Khelat Survey, Sukkur, India.

Year of Election.

1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
1868. ‡DEWAR, JAMES, M.A., LL.D., F.R.S., F.R.S.E., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London, and Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 1 Scroope-terrace, Cambridge.
1881. ‡Dewar, Mrs. 1 Scroope-terrace, Cambridge.
1883. ‡Dewar, James, M.D., F.R.C.S.E. Drylaw House, Davidson's Mains, Midlothian, N.B.
1884. *Dewar, William, M.A. Rugby School, Rugby.
1872. ‡Dewick, Rev. E. S., M.A., F.G.S. 26 Oxford-square, London, W.
1887. ‡DE WINTON, Colonel Sir F., G.C.M.G., C.B., D.C.L., LL.D., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1884. ‡De Wolf, O. C., M.D. Chicago, U.S.A.
1873. *DEW-SMITH, A. G., M.A. Trinity College, Cambridge.
1889. ‡Dickinson, A. H. Portland House, Newcastle-upon-Tyne.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-upon-Tyne.
1887. ‡Dickinson, Joseph, F.G.S. South Bank, Pendleton.
1884. ‡Dickson, Charles R., M.D. Wolfe Island, Ontario, Canada.
1881. ‡Dickson, Edmund. West Cliff, Preston.
1887. §Dickson, H. N. 125 Woodstock-road, Oxford.
1885. ‡Dickson, Patrick. Laurencekirk, Aberdeen.
1883. ‡Dickson, T. A. West Cliff, Preston.
1862. *DILKE, The Right Hon. Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1877. ‡Dillon, James, M.Inst.C.E. 36 Dawson-street, Dublin.
1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1876 ‡*Ditchfield, Arthur. 12 Taviton-street, Gordon-square, London, W.C.*
1884. ‡Dix, John William H. Bristol.
1874. *DIXON, A. E., M.D., Professor of Chemistry in Queen's College, Cork. Mentone Villa, Sunday's Well, Cork.
1883. ‡Dixon, Miss E. 2 Cliff-terrace, Kendal.
1888. §Dixon, Edward T. Messrs. Lloyds, Barnetts, & Bosanquets' Bank, 54 St. James's-street, London, S.W.
1886. ‡Dixon, George. 42 Augustus-road, Edgbaston, Birmingham.
1879. *DIXON, HAROLD B., M.A., F.R.S., F.C.S., Professor of Chemistry in the Owens College, Manchester. Birch Hall, Rusholme, Manchester.
1885. ‡Dixon, John Henry. Inveran, Poolewe, Ross-shire, N.B.
1887. ‡Dixon, Thomas. Buttershaw, near Bradford, Yorkshire.
1885. ‡Doak, Rev. A. 15 Queen's-road, Aberdeen.
1890. ‡Dobbie, James J., D.Sc. University College, Bangor, North Wales.
1885. §Dobbin, Leonard. The University, Edinburgh.
1860. *Dobbs, Archibald Edward, M.A. 34 Westbourne-park, London, W.
1892. ‡Dobie, W. Fraser. 47 Grange-road, Edinburgh.
1891. ‡Dobson, G. Alkali and Ammonia Works, Cardiff.
1878. *DOBSON, G. E., M.A., M.B., F.R.S., F.L.S. Adrigole, Spring Grove, Isleworth.
1893. §Dobson, W. E., J.P. Lenton-road, The Park, Nottingham.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
1875. *Docwra, George, jun. 32 Union-street, Coventry.
1870. *Dodd, John. Nunthorpe-avenue, York.
1876. ‡Dodds, J. M. St. Peter's College, Cambridge.

Year of Election.

1889. ‡Dodson, George, B.A. Downing College, Cambridge.
1893. §Donald, Charles W. Kinsgarth, Braid-road, Edinburgh.
1885. ‡Donaldson, James, M.A., LL.D., F.R.S.E., Senior Principal of the University of St. Andrews, N.B.
1882. ‡Donaldson, John. Tower House, Chiswick, Middlesex.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1877. *Donkin, Bryan, jun. May's Hill, Shortlands, Kent.
1889. ‡Donkin, R. S., M.P. Campville, North Shields.
1861. ‡Donnelly, Major-General Sir J. F. D., R.E., K.C.B. South Kensington Museum, London, S.W.
1887. ‡*Donner, Edward, B.A. 4 Anson-road, Victoria Park, Manchester.*
1887. ‡Dorning, Elias, M.Inst.C.E., F.G.S. 41 John Dalton-street, Manchester.
1881. ‡Dorrington, John Edward. Lypiatt Park, Stroud.
1889. ‡*Dorsey, E. B. International Club, Trafalgar-square, London, S.W.*
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, Charles Montagu. Care of H. M. Doughty, Esq., 5 Stone-court, Lincoln's Inn, London, W.C.
1876. **Douglas, Rev. G. C. M., D.D. 18 Royal-crescent West, Glasgow.*
1877. *Douglass, Sir James N., F.R.S., M.Inst.C.E. Stella House, Dulwich, London, S.E.
1884. ‡Douglass, William Alexander. Freehold Loan and Savings Company, Church-street, Toronto, Canada.
1890. ‡Dovaston, John. West Felton, Oswestry.
1883. ‡Dove, Arthur. Crown Cottage, York.
1884. ‡Dove, Miss Frances. St. Leonard's, St. Andrews, N.B.
1884. ‡Dove, P. Edward, F.R.A.S., Sec.R.Hist.Soc. 23 Old-buildings, Lincoln's Inn, London, W.C.
1884. ‡Dowe, John Melnotte. 69 Seventh-avenue, New York, U.S.A.
1876. ‡Dowie, Mrs. Muir. Golland, by Kinross, N.B.
1884. *Dowling, D. J. Bromley, Kent.
1857. ‡Downing, S., LL.D. 4 The Hill, Monkstown, Co. Dublin.
1865. *Dowson, E. Theodore, F.R.M.S. Geldeston, near Beccles, Suffolk.
1881. *Dowson, Joseph Emerson, M.Inst.C.E. 3 Great Queen-street, London, S.W.
1887. §Doxey, R. A. Slade House, Levenshulme, Manchester.
1883. ‡Draper, William. De Grey House, St. Leonard's, York.
1892. *Dreghorn, David, J.P. Greenwood, Pollokshields, Glasgow.
1868. ‡Dresser, Henry E., F.Z.S. 110 Cannon-street, London, E.C.
1890. ‡Drew, John. 12 Harringay-park, Crouch End, Middlesex, N.
1892. ‡Dreyer, John L. E., M.A., Ph.D., F.R.A.S. The Observatory, Armagh.
1887. ‡Dreyfus, Dr. Daisy Mount, Victoria Park, Manchester.
1893. §Druce, G. Claridge, M.A., F.L.S. 118 High-street, Oxford.
1889. ‡Drummond, Dr. 6 Saville-place, Newcastle-upon-Tyne.
1892. ‡Du Bois, Dr. H. Mittelstrasse, 39, Berlin.
1889. ‡Du Chaillu, Paul B. Care of John Murray, Esq., 50A Albemarle-street, London, W.
1856. *Ducie, The Right. Hon. Henry John Reynolds Moreton, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. Christchurch Vicarage, Chester.
1867. *Duff, The Right Hon. Sir Mountstuart Elphinstone Grant-, G.C.S.I., F.R.S., Pres.R.G.S. York House, Twickenham.
1852. ‡Dufferin and Ava, The Most Hon. the Marquis of, K.P., G.C.B., G.C.M.G., G.C.S.I., D.C.L., LL.D., F.R.S., F.R.G.S. Clandeboye, near Belfast, Ireland.

Year of Election.

1877. ‡Duffey, George F., M.D. 30 Fitzwilliam-place, Dublin.
1875. ‡Duffin, W. E. L'Estrange. Waterford.
1890. ‡Dufton, S. F. Trinity College, Cambridge.
1884. ‡Dugdale, James H. 9 Hyde Park-gardens, London, W.
1883. §Duke, Frederic. Conservative Club, Hastings.
1892. ‡Dulier, Colonel E., C.B. 27 Sloane-gardens, London, S.W.
1866. *Duncan, James. 9 Mincing-lane, London, E.C.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1891. *Duncan, John, J.P. 'South Wales Daily News' Office, Cardiff.
1880. ‡Duncan, William S. 143 Queen's-road, Bayswater, London, W.
1881. ‡Duncombe, The Hon. Cecil. Nawton Grange, York.
1893. *Dunell, George Robert. 9 Grove Park-terrace, Chiswick, London, W.
1892. ‡Dunham, Miss Helen Bliss. Messrs. Morton, Rose, & Co., Bartholomew House, London, E.C.
1881. ‡Dunhill, Charles H. Gray's-court, York.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1882. ‡Dunn, J. T., M.Sc., F.C.S. High School for Boys, Gateshead-on-Tyne.
1883. ‡Dunn, Mrs. Denton Grange, Gateshead-on-Tyne.
1876. ‡Dunnachie, James. 2 West Regent-street, Glasgow.
1878. ‡Dunne, D. B., M.A., Ph.D., Professor of Logic in the Catholic University of Ireland. 4 Clanwilliam-place, Dublin.
1884. §Dunnington, F. P. University Station, Charlottesville, Virginia, U.S.A.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1890. ‡*Dunsford, Follett. Rougemont Villa, Headingley, Leeds.*
1893. *Dunstan, M. J. R. 9 Hamilton-drive, Nottingham.
1885. *DUNSTAN, WYNDHAM R., M.A., F.R.S., Sec.C.S., Lecturer on Chemistry at St. Thomas's Hospital and Professor of Chemistry to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1866. ‡*Duprey, Perry. Woodberry Down, Stoke Newington, London, N.*
1869. ‡D'Urban, W. S. M., F.L.S. Moorlands, Exmouth, Devon.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
1887. ‡Dyason, John Sanford, F.R.G.S., F.R.Met.Soc. Boscobel-gardens, London, N.W.
1884. ‡Dyck, Professor Walter. The University, Munich.
1885. *Dyer, Henry, M.A., D.Sc. 8 Highburgh-terrace, Dowanhill, Glasgow.
1869. *Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. ‡Eade, Sir Peter, M.D. Upper St. Giles's-street, Norwich.
1877. ‡Earle, Ven. Archdeacon, M.A. West Alvington, Devon.
1888. ‡Earson, H. W. P. 11 Alexandra-road, Clifton, Bristol.
1874. ‡Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON, EDWARD, M.Inst.C.E., F.G.S. 11 Delahay-street, Westminster, S.W.
1863. ‡Easton, James. Nest House, near Gateshead, Durham.
1876. ‡Easton, John. Durie House, Abercromby-street, Helensburgh, N.B.
1883. ‡Eastwood, Miss. Littleover Grange, Derby.
1893. §Ebbs, Alfred B. Northumberland-alley, Fenchurch-street, London, E.C.
1887. *Eccles, Mrs. S. White Coppice, Chorley, Lancashire.
1884. ‡Eckersley, W. T. Standish Hall, Wigan, Lancashire.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.

Year of Election.

1870. *Eddison, John Edwin, M.D., M.R.C.S. 6 Park-square, Leeds.
*Eddy, James Ray, F.G.S. The Grange, Carleton, Skipton.
1887. ‡Ede, Francis J. Silchar, Cachar, India.
Eden, Thomas. Talbot-road, Oxton.
1884. *Edgell, Rev. R. Arnold, M.A., F.C.S. 66 Warwick-road, South Kensington, London, S.W.
1887. §Edgeworth, F. Y., M.A., D.C.L., F.S.S., Professor of Political Economy in the University of Oxford. All Souls College, Oxford.
1870. *Edmonds, F. B. 6 Furnival's Inn, London, E.C.
1883. ‡Edmonds, William. Wiscombe Park, Honiton, Devon.
1888. *Edmunds, Henry. Antron, 71 Upper Tulse-hill, London, S.W.
1884. *Edmunds, James, M.D. 29 Dover-street, Piccadilly, London, W.
1883. ‡Edmunds, Lewis, D.Sc., LL.B. 60 Park-street, Park-lane, London, W.
1867. *Edward, Allan. Farington Hall, Dundee.
1855. *Edwards, Professor J. Baker, Ph.D., D.C.L. Montreal, Canada.
1884. ‡Edwards, W. F. Niles, Michigan, U.S.A.
1887. *Egerton of Tatton, The Right Hon. Lord. Tatton Park, Knutsford.
1876. ‡Elder, Mrs. 6 Claremont-terrace, Glasgow.
1890. §Elford, Percy. Christ Church, Oxford.
1885. *Elgar, Francis, LL.D., M.Inst.C.E., F.R.S.E. 113 Cannon-street, London, E.C.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. Manor Cottage, Kempston, Bedford.
1863. ‡*Ellenberger, J. L. Worksop.*
1885. ‡Ellingham, Frank. Thorpe St. Andrew, Norwich.
1883. ‡Ellington, Edward Bayzand, M.Inst.C.E. Palace-chambers, Bridge-street, Westminster, S.W.
1891. ‡Elliott, A. C., D.Sc. Professor of Engineering in University College, Cardiff.
1864. ‡Elliott, E. B. Washington, U.S.A.
1883. *Elliott, Edwin Bailey, M.A., F.R.S., F.R.A.S., Waynflete Professor of Pure Mathematics in the University of Oxford. Queen's College, Oxford.
Elliott, John Fogg. Elvet Hill, Durham.
1879. ‡Elliott, Joseph W. Post Office, Bury, Lancashire.
1886. ‡Elliott, Thomas Henry, F.S.S. Board of Agriculture, 4 Whitehall-place, London, S.W.
1877. ‡Ellis, Arthur Devonshire. Thurnscoe Hall, Rotherham, Yorkshire.
1875. *Ellis, H. D. 6 Westbourne-terrace, Hyde Park, London, W.
1883. ‡Ellis, John. 17 Church-street, Southport.
1880. *Ellis, John Henry. Woodland House, Plymouth.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1891. §Ellis, Miss M. A. 2 Southwick-place, London, W.
1884. ‡Ellis, W. Hodgson. Toronto, Canada.
1869. ‡Ellis, William Horton. Hartwell House, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1887. ‡Elmy, Ben. Congleton, Cheshire.
1862. ‡Elphinstone, H. W., M.A., F.L.S. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1883. ‡Elwes, George Robert. Bossington, Bournemouth.
1887. §Elworthy, Frederick T. Foxdown, Wellington, Somerset.
1870. *Ely, The Right Rev. Lord Alwyne Compton, D.D., Lord Bishop of. The Palace, Ely, Cambridgeshire.
1863. ‡Embleton, Dennis, M.D. 19 Claremont-place, Newcastle-upon-Tyne.
1891. ‡Emerton, Wolseley. Banwell Castle, Somerset.

Year of Election.

1891. ‡Emerton, Mrs. Wolseley. Banwell Castle, Somerset.
1884. ‡Emery, Albert H. Stamford, Connecticut, U.S.A.
1863. ‡Emery, The Ven. Archdeacon, B.D. Ely, Cambridgeshire.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1890. ‡Emsley, Alderman W. Richmond House, Richmond-road, Headingley, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1884. ‡England, Luther M. Knowlton, Quebec, Canada.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡*English, J. T. Wayfield House, Stratford-on-Avon.*
1883. ‡Entwistle, James P. Beachfield, 2 Westclyffe-road, Southport.
1869. *Enys, John Davis. Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.
1844. ‡Erichsen, John Eric, LL.D., F.R.S., F.R.C.S., President of, and Emeritus Professor of Surgery in, University College, London. 6 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1885. ‡Esselmont, Peter. 34 Albyn-place, Aberdeen.
1862. *Esson, William, M.A., F.R.S., F.C.S., F.R.A.S. Merton College, and 13 Bradmore-road, Oxford.
1878. ‡Estcourt, Charles, F.C.S. 8 St. James's-square, John Dalton-street, Manchester.
1887. *Estcourt, Charles. Vyrniew House, Talbot-road, Old Trafford, Manchester.
1887. *Estcourt, P. A. Vyrniew House, Talbot-road, Old Trafford, Manchester.
1869. ‡Etheridge, Robert, F.R.S., F.R.S.E., F.G.S. 14 Carlyle-square, London, S.W.
1888. ‡Etheridge, Mrs. 14 Carlyle-square, London, S.W.
1883. §Eunson, Henry J., F.G.S., Assoc.M.Inst.C.E. Vizianagram, Madras.
1891. ‡Evan-Thomas, C., J.P. The Gnoll, Neath, Glamorganshire.
1881. ‡Evans, Alfred, M.A., M.B. Pontypridd.
1889. *Evans, A. H. 9 Harvey-road, Cambridge.
1887. *Evans, Mrs. Alfred W. A. Hillside, New Mills, near Stockport, Derbyshire.
1870. *Evans, Arthur John, F.S.A. 33 Holywell, Oxford.
1865. *Evans, Rev. Charles, M.A. The Rectory Solihull, Birmingham.
1891. ‡Evans, Franklen. Llwynarthen Castleton, Cardiff.
1889. ‡Evans, Henry Jones. Greenhill, Whitchurch, Cardiff.
1884. ‡Evans, Horace L. 6 Albert-buildings, Weston-super-Mare.
1883. *Evans, James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.
1883. *Evans, Mrs. James C. Morannedd, Eastbourne-road West, Birkdale Park, Southport.
1861. *Evans, Sir John, K.C.B., D.C.L., LL.D., D.Sc., Treas.R.S., F.S.A., F.L.S., F.G.S. Nash Mills, Hemel Hempstead.
1881. ‡Evans, Lewis. Llanfyrnach R.S.O., Pembrokeshire.
1885. **Evans, Percy Bagnall. The Spring, Kenilworth.*
1875. ‡Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1865. *Evans, William. The Spring, Kenilworth.
1891. ‡Evans, William Llewellin. Guildhall-chambers, Cardiff.
1886. ‡Eve, A. S. Marlborough College, Wilts.
1871. ‡Eve, H. Weston, M.A. University College, London, W.C.
1868. *Everett, J. D., M.A., D.C.L., F.R.S., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Derryvolgie, Belfast.

Year of Election.

1863. *Everitt, George Allen, F.R.G.S. Knowle Hall, Warwickshire.
1886. ‡Everitt, William E. Finstall Park, Bromsgrove.
1883. ‡Eves, Miss Florence. Uxbridge.
1881. ‡EWART, J. COSSAR, M.D., F.R.S., Professor of Natural History in the University of Edinburgh.
1874. ‡Ewart, Sir W. Quartus, Bart. Glenmachan, Belfast.
1876. *EWING, JAMES ALFRED, M.A., B.Sc., F.R.S., F.R.S.E., Professor of Mechanism and Applied Mathematics in the University of Cambridge.
1883. ‡Ewing, James L. 52 North Bridge, Edinburgh.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1884. *Eyerman, John. Oakhurst, Easton, Pennsylvania, U.S.A.
1882. ‡Eyre, G. E. Briscoe. Warrens, near Lyndhurst, Hants.
Eyton, Charles. Hendred House, Abingdon.

1890. ‡FABER, EDMUND BECKETT. Straylea, Harrogate.
1891. *Faija, Henry, M.Inst.C.E. 41 Old Queen-street, London, S.W.
1865. *FAIRLEY, THOMAS, F.R.S.E., F.C.S. 8 Newton-grove, Leeds.
1886. ‡Fairley, William. Beau Desert, Rugeley, Staffordshire.
1864. ‡*Falkner, F. H. Lyncombe, Bath.*
1883. ‡Fallon, Rev. W. S. 1 St. Alban's-terrace, Cheltenham.
1877. §FARADAY, F. J., F.L.S., F.S.S. College-chambers, 17 Brazenose-street, Manchester.
1891. ‡Fards, G. Penarth.
1892. *Farmer, J. Bretland, M.A., F.L.S. Magdalen College, Oxford.
1886. ‡Farncombe, Joseph, J.P. Lewes.
1879. *Farnworth, Ernest. Rosslyn, Goldthorn Hill, Wolverhampton.
1883. ‡Farnworth, Walter. 86 Preston New-road, Blackburn.
1883. ‡Farnworth, William. 86 Preston New-road, Blackburn.
1885. ‡Farquhar, Admiral. Carlogie, Aberdeen.
1859. ‡Farquharson, Robert F. O. Haughton, Aberdeen.
1885. ‡Farquharson, Mrs. R. F. O. Haughton, Aberdeen.
1866. *FARRAR, Ven. FREDERIC WILLIAM, M.A., D.D., F.R.S., Archdeacon of Westminster. 17 Dean's-yard Westminster, S.W.
1883. ‡Farrell, John Arthur. Moynalty, Kells, North Ireland.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulding, Joseph. Boxley House, Tenterden, Kent.
1883. ‡Faulding, Mrs. Boxley House, Tenterden, Kent.
1887. §Faulkner, John. 13 Great Ducie-street, Strangeways, Manchester.
1890. *Fawcett, F. B. University College, Bristol.
1886. §Felkin, Robert W., M.D., F.R.G.S. 8 Alva-street, Edinburgh.
Fell, John B. Spark's Bridge, Ulverstone, Lancashire.
1864. *FELLOWS, FRANK P., K.S.J.J., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. Keswick, near Belfast.
1883. ‡Fenwick, E. H. 29 Harley-street, London, W.
1890. ‡Fenwick, T. Chapel Allerton, Leeds.
1876. ‡Ferguson, Alexander A. 11 Grosvenor-terrace, Glasgow.
1883. ‡Ferguson, Mrs. A. A. 11 Grosvenor-terrace, Glasgow.
1871. *FERGUSON, JOHN, M.A., LL.D., F.R.S.E., F.S.A., F.C.S., Professor of Chemistry in the University of Glasgow.
1867. ‡Ferguson, Robert M., LL.D., Ph.D., F.R.S.E. 5 Learmouth-terrace, Edinburgh.
1867. **Fergusson, H. B. 13 Airlie-place, Dundee.*
1883. ‡Fernald, H. P. Alma House, Cheltenham.
1883. *Fernie, John. Box No. 2, Hutchinson, Kansas, U.S.A.

Year of Election.

1862. ‡FERRERS, Rev. NORMAN MACLEOD, D.D., F.R.S. Caius College Lodge, Cambridge.
1873. ‡Ferrier, David, M.A., M.D., LL.D., F.R.S., Professor of Neuro-Pathology in King's College, London. 34 Cavendish-square, London, W.
1892. ‡Ferrier, Robert M., B.Sc. College of Science, Newcastle-upon-Tyne.
1882. §Fewings, James, B.A., B.Sc. The Grammar School, Southampton.
1887. ‡Fiddes, Thomas, M.D. Penwood, Urmston, near Manchester.
1875. ‡Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1886. ‡Field, H. C. 4 Carpenter-road, Edgbaston, Birmingham.
1869. *FIELD, ROGERS, B.A., M.Inst.C.E. 4 Westminster-chambers, Westminster, S.W.
1887. ‡*Fielden, John C. 145 Upper Brook-street, Manchester.*
1882. ‡Filliter, Freeland. St. Martin's House, Wareham, Dorset.
1883. *Finch, Gerard B., M.A. 1 St. Peter's-terrace, Cambridge.
Finch, John. Bridge Work, Chepstow.
1878. *Findlater, William. 22 Fitzwilliam-square, Dublin.
1885. ‡*Findlay, George, M.A. 50 Victoria-street, Aberdeen.*
1892. ‡Findlay, J. R., B.A. 3 Rothesay-terrace, Edinburgh.
1884. ‡Finlay, Samuel. Montreal, Canada.
1887. ‡Finnemore, Rev. J., M.A., Ph.D., F.G.S. 12 College-road, Brighton.
1881. ‡Firth, Colonel Sir Charles. Heckmondwike.
Firth, Thomas. Northwich.
1891. ‡Fisher, Major H. O. The Highlands, Llandough, near Cardiff.
1884. *Fisher, L. C. Galveston, Texas, U.S.A.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlton Rectory, near Cambridge.
1873. ‡Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1879. ‡*Fisher, William. Norton Grange, near Sheffield.*
1875. *Fisher, W. W., M.A., F.C.S. 5 St. Margaret's-road, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1887. *Fison, Alfred H., D.Sc. University College, London, W.C.
1885. ‡Fison, E. Herbert. Stoke House, Ipswich.
1871. *FISON, FREDERICK W., M.A., F.C.S. Greenholme, Burley-in-Wharfedale, near Leeds.
1871. ‡FITCH, J. G., M.A., LL.D. 5 Lancaster-terrace, Regent's Park, London, N.W.
1883. ‡Fitch, Rev. J. J. Ivyholme, Southport.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1878. ‡Fitzgerald, C. E., M.D. 27 Upper Merrion-street, Dublin.
1878. §FITZGERALD, GEORGE FRANCIS, M.A., D.Sc., F.R.S., Professor of Natural and Experimental Philosophy, Trinity College, Dublin.
1885. *Fitzgerald, Professor Maurice, B.A. 69 Botanic-avenue, Belfast.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Baggot-street, Dublin.
1888. *Fitzpatrick, Rev. Thomas C. Christ's College, Cambridge.
1865. ‡*Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.*
1881. ‡Fleming, Rev. Canon J., B.D. St. Michael's Vicarage, Ebury-square, S.W.
1876. ‡Fleming, James Brown. Beaconsfield, Kelvinside, near Glasgow.
1876. ‡Fleming, Sandford. Ottawa, Canada.
1867. §FLETCHER, ALFRED E., F.C.S. 13 Christchurch-street, Crouch End, London, N.
1870. ‡Fletcher, B. Edgington. Norwich.
1890. ‡Fletcher, B. Morley. 12 Trevor-square, London, S.W.
1892. §Fletcher, George. 59 Wilson-street, Derby.

Year of Election.

1869. ‡FLETCHER, LAVINGTON E., M.Inst.C.E. Alderley Edge, Cheshire.
1888. *FLETCHER, LAZARUS, M.A., F.R.S., F.G.S., F.C.S., Keeper of Minerals, British Museum (Natural History), Cromwell-road, London, S.W. 36 Woodville-road, Ealing, London, W.
1862. §FLOWER, Sir WILLIAM HENRY, K.C.B., LL.D., D.C.L., D.Sc., F.R.S., F.L.S., F.G.S., F.R.C.S., Director of the Natural History Departments, British Museum, South Kensington, London. 26 Stanhope-gardens, London, S.W.
1889. ‡Flower, Lady. 26 Stanhope-gardens, London, S.W.
1877. *Floyer, Ernest A., F.R.G.S., F.L.S. Helwan, Egypt.
1890. *Flux, A. W., M.A. Owens College, Manchester.
1887. ‡Foale, William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1883. ‡Foale, Mrs. William. 3 Meadfoot-terrace, Mannamead, Plymouth.
1891. §Földvary, William. Museum Ring, 10, Buda Pesth.
1879. ‡Foote, Charles Newth, M.D. 3 Albion-place, Sunderland.
1880. ‡Foote, R. Bruce. Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.
1873. *FORBES, GEORGE, M.A., F.R.S., F.R.S.E., M.Inst.C.E. 34 Great George-street, London, S.W.
1883. ‡FORBES, HENRY O., F.Z.S., Director of the Museum. Liverpool.
1885. ‡Forbes, The Right Hon. Lord. Castle Forbes, Aberdeenshire.
1890. ‡FORD, J. RAWLINSON. Quarry Dene, Weetwood-lane, Leeds.
1875. *FORDHAM, H. GEORGE, F.G.S. Odsey, Ashwell, Baldock, Herts.
1883. §Formby, R. Kirklake Bank, Formby, near Liverpool.
1887. ‡FORREST, Sir JOHN, K.C.M.G., F.R.G.S. Perth, Western Australia.
1867. ‡Forster, Anthony. Finlay House, St. Leonards-on-Sea.
1883. ‡Forsyth, A. R., M.A., D.Sc., F.R.S. Trinity College, Cambridge.
1884. ‡Fort, George H. Lakefield, Ontario, Canada.
1877. ‡FORTESCUE, The Right Hon. the Earl. Castle Hill, North Devon.
1882. §Forward, Henry. 10 Marine-avenue, Southend.
1870. ‡Forwood, Sir William B. Hopeton House, Seaforth, Liverpool.
1875. ‡Foster, A. Le Neve. 51 Cadogan-square, London, S.W.
1865. ‡Foster, Balthazar, M.D., Professor of Medicine in Queen's College, Birmingham. 16 Temple-row, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.R.S., F.G.S., Professor of Mining in the Royal College of Science, London. Llandudno.
1883. ‡Foster, Mrs. C. Le Neve. Llandudno.
1857. *FOSTER, GEORGE CAREY, B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 18 Daleham-gardens, Hampstead, London, N.W.
1877. §Foster, Joseph B. 6 James-street, Plymouth.
1859. *FOSTER, MICHAEL, M.A., M.D., LL.D., Sec.R.S., F.L.S., F.C.S., Professor of Physiology in the University of Cambridge. Shelford, Cambridge.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1866. ‡Fowler, George, M.Inst.C.E., F.G.S. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1888. §Fowler, Gilbert J. Dalton Hall, Manchester.
1892. §Fowler, Miss Jessie A. 4 & 5 Imperial-buildings, Ludgate-circus, London, E.C.
1876. *Fowler, John. 16 Kerrsland-street, Hillhead, Glasgow.
1882. ‡FOWLER, Sir JOHN, Bart., K.C.M.G., M.Inst.C.E., F.G.S. 2 Queen Square-place, Westminster, S.W.
1884. ‡Fox, Miss A. M. Penjerrick, Falmouth.
1883. *Fox, Charles. The Cedars, Warlingham, Surrey.
1883. §Fox, Sir Charles Douglas, M.Inst.C.E. 28 Victoria-street, Westminster, S.W.

Year of Election.

1883. ‡Fox, Howard, F.G.S. Falmouth.
1847. *Fox, Joseph Hoyland. The Cleve, Wellington, Somerset.
1888. ‡Fox, Thomas. Court, Wellington, Somerset.
1886. ‡Foxwell, Arthur, M.A., M.B. 17 Temple-row, Birmingham.
1881. *FOXWELL, HERBERT S., M.A., F.S.S., Professor of Political Economy in University College, London. St. John's College, Cambridge.
1889. ‡Frain, Joseph, M.D. Grosvenor-place, Jesmond, Newcastle-upon-Tyne.
1866. *Francis, G. B. Inglesby, North-road, Hertford.
1884. ‡Francis, James B. Lowell, Massachusetts, U.S.A.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1845. ‡FRANKLAND, EDWARD, M.D., D.C.L., LL.D., Ph.D., F.R.S., F.C.S. The Yews, Reigate Hill, Surrey.
1887. *FRANKLAND, PERCY F., Ph.D., B.Sc., F.R.S., Professor of Chemistry in University College, Dundee.
1889. ‡Franklin, Rev. Canon. Clayton-street West, Newcastle-upon-Tyne.
1882. ‡Fraser, Alexander, M.B. Royal College of Surgeons, Dublin.
1885. ‡FRASER, ANGUS, M.A., M.D., F.C.S. 232 Union-street, Aberdeen.
1859. ‡*Fraser, George B. 3 Airlie-place, Dundee.*
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S., F.R.S.E., Professor of Materia Medica and Clinical Medicine in the University of Edinburgh. 13 Drumsheugh-gardens, Edinburgh.
1859. *Frazer, Daniel. 127 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1884. *Frazer, Persifor, M.A., D.Sc. (Univ. de France). Room 1042, Drexel Building, Philadelphia, U.S.A.
1884. *FREAM, W., LL.D., B.Sc., F.L.S., F.G.S., F.S.S. The Vinery, Downton, Salisbury.
1877. §Freeman, Francis Ford. Abbotsfield, Tavistock, South Devon.
1865. ‡*Freeman, James. 15 Francis-road, Edgbaston, Birmingham.*
1884. *FREMANTLE, The Hon. Sir C. W., K.C.B. Royal Mint, London, E.
1869. ‡Frere, Rev. William Edward. The Rectory, Bitton, near Bristol.
1886. ‡Freshfield, Douglas W., Sec.R.G.S. 1 Savile-row, London, W.
1886. ‡*Freund, Miss Ida. Eyre Cottage, Upper Sydenham, S.E.*
1887. ‡Fries, Harold H., Ph.D. 92 Reade-street, New York, U.S.A.
1887. ‡Froehlich, The Chevalier. Grosvenor-terrace, Withington, Manchester.
1892. *Frost, Edmund. The Elms, Lasswade, Midlothian.
1882. §Frost, Edward P., J.P. West Wratting Hall, Cambridgeshire.
1883. ‡Frost, Major H., J.P. West Wratting Hall, Cambridgeshire.
1887. *Frost, Robert, B.Sc. St. James's-chambers, Duke-street, London, S.W.
1875. ‡Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
1875. *Fry, Joseph Storrs. 13 Upper Belgrave-road, Clifton, Bristol.
1884. §Fryer, Joseph, J.P. Smelt House, Howden-le-Wear, Co. Durham.
1872. *Fuller, Rev. A. Pallant, Chichester.
1859. ‡FULLER, FREDERICK, M.A. 9 Palace-road, Surbiton.
1869. ‡FULLER, GEORGE, M.Inst.C.E. 71 Lexham-gardens, Kensington, London, W.
1884. §Fuller, William. Oswestry.
1891. ‡Fulton, Andrew. 23 Park-place, Cardiff.

1881. ‡Gabb, Rev. James, M.A. Bulmer Rectory, Welburn, Yorkshire.
1887. ‡Gaddum, G. H. Adria House, Toy-lane, Withington, Manchester.

Year of Election.

1836. *Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡GAGES, ALPHONSE, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Skendleby Hall, Spilsby.
1876. ‡Gairdner, Charles. Broom, Newton Mearns, Renfrewshire.
1850. ‡Gairdner, W. T., M.D., F.R.S., LL.D., Professor of Medicine in the University of Glasgow. The University, Glasgow.
1876. ‡Gale, James M. 23 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 225 Oxford-street, London, W.
1885. *Gallaway, Alexander. Dirgarve, Aberfeldy, N.B.
1888. ‡Gallenga, Mrs. Anna. The Falls, Chepstow.
1888. ‡Gallenga, Mrs. A. A. R. The Falls, Chepstow.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1889. ‡Galloway, Walter. Eighton Banks, Gateshead.
1875. ‡GALLOWAY, W. Cardiff.
1887. *Galloway, W. The Cottage, Seymour-grove, Old Trafford, Manchester.
1860. *GALTON, Sir DOUGLAS, K.C.B., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, M.A., F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 40 Great Marlborough-street, London, W.
1870. §Gamble, Lieut.-Colonel D., C.B. St. Helens, Lancashire.
1889. §Gamble, David, jun. St. Helens, Lancashire.
1870. ‡Gamble, J. C. St. Helens, Lancashire.
1888. *Gamble, J. Sykes, M.A., F.L.S. Dehra Dún, North-West Provinces, India.
1877. ‡Gamble, William. St. Helens, Lancashire.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S. Davos, Switzerland.
1889. ‡Gamgee, John. 6 Lingfield-road, Wimbledon, Surrey.
1883. ‡Gant, Major John Castle. St. Leonards.
1887. ‡GARDINER, WALTER, M.A., F.R.S., F.L.S. Clare College, Cambridge.
1882. *Gardner, H. Dent, F.R.G.S. 25 Northbrook-road, Lee, Kent.
1882. ‡GARDNER, JOHN STARKIE, F.G.S. 29 Albert Embankment, London, S.E.
1884. ‡Garman, Samuel. Cambridge, Massachusetts, U.S.A.
1888. §Garnett, Frederick Brooksbank, C.B., F.S.S. 4 Argyll-road, Kensington, London, W.
1887. *Garnett, Jeremiah. The Grange, near Bolton, Lancashire.
1882. ‡Garnett, William, D.C.L., London County Council.
1873. ‡Garnham, John. Hazelwood, Crescent-road, St. John's, Brockley, Kent, S.E.
1883. §GARSON, J. G., M.D. 32 Duke-street, St. James's, London, S.W.
1874. *Garstin, John Ribton, M.A., LL.B., M.R.I.A., F.S.A. Bragans-town, Castlebellingham, Ireland.
1882. ‡Garton, William. Woolston, Southampton.
1892. §Garvie, James. Springfield-road, New Southgate, London, N.
1889. ‡Garwood, E. J. Trinity College, Cambridge.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Clayton Lodge, Aigburth, Liverpool.
1862. *Gatty, Charles Henry, M.A., LL.D., F.L.S., F.G.S. Felbridge Place, East Grinstead, Sussex.
1890. ‡Gaunt, Sir Edwin. Carlton Lodge, Leeds.
1875. ‡Gavey, J. 43 Stacey-road, Routh, Cardiff.
1875. ‡Gaye, Henry S., M.D. Newton Abbot, Devon.

Year of Election.

1892. ‡Geddes, George H. 8 Douglas-crescent, Edinburgh.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1883. ‡Geddes, John. 33 Portland-street, Southport.
1885. ‡Geddes, Professor Patrick. 6 James-court, Edinburgh.
1887. ‡Gee, W. W. Haldane. Owens College, Manchester.
1867. ‡GEIKIE, Sir ARCHIBALD, LL.D., D.Sc., F.R.S., F.R.S.E., F.G.S., Director-General of the Geological Survey of the United Kingdom. Geological Survey Office, Jermyn-street, London, S.W.
1871. ‡GEIKIE, JAMES, LL.D., D.C.L., F.R.S., F.R.S.E., F.G.S., Murchison Professor of Geology and Mineralogy in the University of Edinburgh. 31 Merchiston-avenue, Edinburgh.
1882. *GENESE, R. W., M.A., Professor of Mathematics in University College, Aberystwith.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1885. ‡Gerard, Robert. Blair-Devenick, Cults, Aberdeen.
1884. *Gerrans, Henry T., M.A. Worcester College, Oxford.
1884. ‡Gibb, Charles. Abbotsford, Quebec, Canada.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1889. ‡Gibson, Charles, M.D. 8 Eldon-square, Newcastle-upon-Tyne.
1874. ‡Gibson, The Right Hon. Edward, Q.C. 23 Fitzwilliam-square, Dublin.
1892. §Gibson, Francis Maitland. 1 Fingal-place, Edinburgh.
1876. *Gibson, George Alexander, M.D., D.Sc., F.R.S.E., Secretary to the Royal College of Physicians of Edinburgh. 17 Alva-street, Edinburgh.
1892. ‡*Gibson, James. 10 North Mansion House-road, Edinburgh.*
1884. ‡Gibson, Rev. James J. 183 Spadina-avenue, Toronto, Canada.
1885. ‡*Gibson, John, Ph.D. 15 Hartington-gardens, Edinburgh.*
1889. *Gibson, T. G. 2 Eslington-road, Newcastle-upon-Tyne.
1893. §Gibson, Walcot, F.G.S. 28 Jermyn-street, London, S.W.
1887. ‡GIFFEN, ROBERT, C.B., LL.D., F.R.S., V.P.S.S. 44 Pembroke-road, London, S.W.
1888. *Gifford, H. J. Lyston Court, Tram Inn, Hereford.
1884. ‡Gilbert, E. E. 245 St. Antoine-street, Montreal, Canada.
1842. GILBERT, SIR JOSEPH HENRY, Ph.D., LL.D., F.R.S., F.C.S., Professor of Rural Economy in the University of Oxford. Harpenden, near St. Albans.
1883. §Gilbert, Lady. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Villa Nova, Blackrock, Dublin.
1884. *Gilbert, Philip H. 1375 Dorchester-street, Montreal, Canada.
1883. ‡*Gilbert, Thomas. Derby-road, Southport.*
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
1882. ‡Giles, Alfred, M.P., M.Inst.C.E. 26 Great George-street, London, S.W.
1878. ‡Giles, Oliver. Crescent Villas, Bromsgrove.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *GILL, DAVID, LL.D., F.R.S., F.R.A.S. Royal Observatory, Cape Town.
1888. §Gill, John Frederick. Douglas, Isle of Man.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1887. ‡Gillett, Charles Edwin. Wood Green, Banbury, Oxford.
1888. ‡Gilliland, E. T. 259 West Seventy-fourth-street, New York, U.S.A.
1884. ‡Gillman, Henry. 130 Lafayette-avenue, Detroit, Michigan, U.S.A.
1892. §Gilmour, Matthew A. B. Saffronhall House, Windmill-road, Hamilton, N.B.

Year of Election.

1867. ‡Gilroy, Robert. Craigie, by Dundee.
1893. *Gimingham, Edward. Stamford House, Northumberland Park, Tottenham, London.
1867. ‡GINSBURG, Rev. C. D., D.C.L., LL.D. Holmlea, Virginia Water Station, Chertsey.
1884. ‡Girdwood, Dr. G. P. 28 Beaver Hall-terrace, Montreal, Canada.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1886. *Gisborne, Hartley. Qu'Appelle Station, Assa, N.W.T., Canada.
1883. *Gladstone, Miss. 17 Pembridge-square, London, W.
1883. *Gladstone, Miss E. A. 17 Pembridge-square, London, W.
1850. *Gladstone, George, F.C.S., F.R.G.S. 34 Denmark-villas, Hove, Brighton.
1849. *GLADSTONE, JOHN HALL, Ph.D., D.Sc., F.R.S., F.C.S. 17 Pembridge-square, London, W.
1890. *Gladstone, Miss Margaret E. 17 Pembridge-square, London, W.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. The Shola, Heathfield-road, South Croydon.
1871. *GLAISHER, J. W. L., M.A., D.Sc., F.R.S., F.R.A.S. Trinity College, Cambridge.
1883. ‡Glasson, L. T. 2 Roper-street, Penrith.
1881. *GLAZEBROOK, R. T., M.A., F.R.S. 7 Harvey-road, Cambridge.
1881. *Gleadow, Frederic. 84 Kensington Park-road, London, W.
1870. ‡Glen, David Corse, F.G.S. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart, M.A. The Shealing, Wimbledon Common, Surrey.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. ‡Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. 124 Manchester-road, Southport.
1870. ‡Glynn, Thomas R., M.D. 62 Rodney-street, Liverpool.
1889. ‡Goddard, F. R. 19 Victoria-square, Newcastle-upon-Tyne.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1886. ‡*Godlee, Arthur. 3 Greenfield-crescent, Edgbaston, Birmingham.*
1887. ‡Godlee, Francis. 51 Portland-street, Manchester.
1878. *Godlee, J. Lister. 3 New-square, Lincoln's Inn, London, W.C.
1880. ‡GODMAN, F. DU CANE, F.R.S., F.L.S., F.G.S. 10 Chandos-street, Cavendish-square, London, W.
1883. ‡Godson, Dr. Alfred. Cheadle, Cheshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1879. §GODWIN-AUSTEN, Lieut.-Colonel H. H., F.R.S., F.G.S., F.R.G.S., F.Z.S. Shalford House, Guildford.
1876. ‡Goff, Bruce, M.D. Bothwell, Lanarkshire.
1881. ‡GOLDSCHMIDT, EDWARD, J.P. Nottingham.
1886. ‡GOLDSMID, Major-General Sir F. J., C.B., K.C.S.I., F.R.G.S. Godfrey House, Hollingbourne.
1873. ‡*Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.*
1890. *Gonner, E. C. K., M.A., Professor of Political Economy in University College, Liverpool.
1884. ‡Good, Charles E. 102 St. François Xavier-street, Montreal, Canada.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1878. ‡Goodbody, Jonathan, jun. 50 Dame-street, Dublin.
1884. ‡Goodbody, Robert. Fairy Hill, Blackrock, Co. Dublin.
1886. ‡*Goodman, F. B. 46 Wheeley's-road, Edgbaston, Birmingham.*
1885. ‡GOODMAN, J. D., J.P. Peachfield, Edgbaston, Birmingham.
1884. *Goodridge, Richard E. W. 1023 The Rookery, Chicago, Illinois, U.S.A.

Year of Election.

1884. ‡Goodwin, Professor W. L. Queen's University, Kingston, Ontario, Canada.
1883. ‡Goouch, B., B.A. 2 Oxford-road, Birkdale, Southport.
1885. ‡Gordon, General the Hon. Sir Alexander Hamilton. 50 Queen's Gate-gardens, London, S.W.
1885. ‡Gordon, Rev. Cosmo, D.D., F.R.A.S., F.G.S. Chetwynd Rectory, Newport, Salop.
1871. *Gordon, Joseph Gordon, F.C.S. Queen Anne's Mansions, Westminster, S.W.
1884. *Gordon, Robert, M.Inst.C.E., F.R.G.S. Care of Messrs. H. S. King & Co., 45 Pall Mall, London, S.W.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1885. ‡Gordon, Rev. William. Braemar, N.B.
1887. ‡Gordon, William John. 3 Lavender-gardens, London, S.W.
1865. ‡Gore, George, LL.D., F.R.S. 67 Broad-street, Birmingham.
1875. *Gotch, Francis, B.A., B.Sc., F.R.S. Professor of Physiology in University College, Liverpool. 11 Prince's Park-terrace, Liverpool.
1873. ‡Gott, Charles, M.Inst.C.E. Parkfield-road, Manningham, Bradford, Yorkshire.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Right Hon. George S., Viscount, M.A., F.L.S., F.G.S. Lough Cutra Castle, Gort, Co. Galway, and St. Helen's, Booterstown, Co. Dublin.
1881. ‡Gough, Thomas, B.Sc., F.C.S. Elmfield College, York.
1888. ‡Gouraud, Colonel. Little Menlo, Norwood, Surrey.
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1867. ‡Gourley, Henry (Engineer). Dundee.
1876. ‡Gow, Robert. Cairndowan, Dowanhill, Glasgow.
1883. §Gow, Mrs. Cairndowan, Dowanhill, Glasgow.
1873. §Goyder, Dr. D. Marley House, 88 Great Horton-road, Bradford, Yorkshire.
1886. ‡Grabham, Michael C., M.D. Madeira.
1875. ‡GRAHAME, JAMES. 12 St. Vincent-street, Glasgow.
1892. §Grange, C. Ernest. Royal Grammar School, Lancaster.
1893. §Granger, F. S., M.A., D.Litt. 2 Cranmer-street, Nottingham.
1892. §Grant, W. B. 10 Ann-street, Edinburgh.
1864. ‡Grantham, Richard F. Northumberland-chambers, Northumberland-avenue, London, W.C.
1881. ‡Gray, Alan, LL.B. Minster-yard, York.
1890. ‡Gray, Professor Andrew, M.A., F.R.S.E. University College, Bangor.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Rotherham.
1865. ‡Gray, Charles. Swan Bank, Bilston.
1876. ‡Gray, Dr. Newton-terrace, Glasgow.
1881. ‡Gray, Edwin, LL.B. Minster-yard, York.
1893. §Gray, J. C., General Secretary of the Co-operative Union, Limited, City-buildings, 69 Corporation-street, Manchester.
1892. *Gray, James H., M.A., B.Sc. The University, Glasgow.
1887. §Gray, Joseph W., F.G.S. Spring Hill, Wellington-road South, Stockport.
1887. ‡Gray, M. H., F.G.S. Lessness Park, Abbey Wood, Kent.
1886. *Gray, Robert Kaye. Lessness Park, Abbey Wood, Kent.
1881. ‡Gray, Thomas, Professor of Engineering in the Rane Technical Institute, Terre Haute, Indiana, U.S.A.
1873. ‡Gray, William, M.R.I.A. 8 Mount Charles, Belfast.

Year of Election.

*Gray, Colonel William. Farley Hall, near Reading.
1883. ‡Gray, William Lewis. 36 Gutter-lane, London, E.C.
1883. ‡Gray, Mrs. W. L. 36 Gutter-lane, London, E.C.
1886. ‡Greaney, Rev. William. Bishop's House, Bath-street, Birmingham.
1883. ‡Greathead, J. H., M.Inst.C.E. 15 Victoria-street, London, S.W.
1866. §Greaves, Charles Augustus, M.B., LL.B. 84 Friar-gate, Derby.
1887. ‡Greaves, H. R. The Orchards, Mill End, Stockport.
1869. ‡Greaves, William. Station-street, Nottingham.
1872. ‡Greaves, William. 33 Marlborough-place, London, N.W.
1893. *Greaves, Mrs. Elizabeth. Station-street, Nottingham.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1889. ‡Green, A. H., M.A., F.R.S., F.G.S., Professor of Geology in the University of Oxford. 137 Woodstock-road, Oxford.
1888. §Green, Joseph R., M.A., B.Sc., F.L.S., Professor of Botany to the Pharmaceutical Society of Great Britain. 17 Bloomsbury-square, London, W.C.
1887. ‡Greene, Friese. 162 Sloane-street, London, S.W.
1887. ‡Greenhalgh, Richard. 1 Temple-gardens, The Temple, London, E.C.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1882. ‡Greenhill, A. G., M.A., F.R.S., Professor of Mathematics in the Royal Artillery College, Woolwich. 10 New Inn, London, W.C.
1881. §Greenhough, Edward. Matlock Bath, Derbyshire.
1884. ‡Greenish, Thomas, F.C.S. 20 New-street, Dorset-square, London, N.W.
1884. ‡Greenshields, E. B. Montreal, Canada.
1884. ‡Greenshields, Samuel. Montreal, Canada.
1887. ‡Greenwell, G. C., jun. Driffield, near Derby.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1889. ‡Greenwell, T. G. Woodside, Sunderland.
1890. ‡Greenwood, Arthur. Cavendish-road, Leeds.
1877. ‡Greenwood, Holmes. 78 King-street, Accrington.
1883. ‡Greenwood, J. G., LL.D. 34 Furness-road, Eastbourne.
1849. ‡Greenwood, William. Stones, Todmorden.
1887. §Greenwood, W. H., M.Inst.C.E. Adderley Park Rolling Mills, Birmingham.
1887. *Greg, Arthur. Eagley, near Bolton, Lancashire.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Sir Charles Hutton, K.C.M.G., M.Inst.C.E. 2 Delahay-street, Westminster, S.W.
1883. ‡Gregson, G. E. Ribble View, Preston.
1881. ‡Gregson, William, F.G.S. Baldersby, S.O., Yorkshire.
1892. §Grey, J. 351 Clarewood-terrace, Brixton, London, S.W.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. ‡Grieve, John, M.D. Care of W. L. Buchanan, Esq., 212 St. Vincent-street, Glasgow.
1878. ‡Griffin, Robert, M.A., LL.D. Trinity College, Dublin.
Griffin, S. F. Albion Tin Works, York-road, London, N.
1859. *Griffith, George, M.A. (Assistant General Secretary.) College-road, Harrow, Middlesex.
1870. ‡Griffith, Rev. Henry, F.G.S. Brooklands, Isleworth, Middlesex.
1884. ‡Griffiths, E. H. 12 Park-side, Cambridge.
1884. ‡Griffiths, Mrs. 12 Park-side, Cambridge.
1891. ‡Griffiths, P. Rhys, B.Sc., M.B. 71 Newport-road, Cardiff.
1847. ‡Griffiths, Thomas. Bradford-street, Birmingham.

Year of Election.

1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1888. *Grimshaw, James Walter. Australian Club, Sydney, New South Wales.
1884. ‡Grinnell, Frederick. Providence, Rhode Island, U.S.A.
1881. ‡Gripper, Edward. Mansfield-road, Nottingham.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY. 18 Elgin-road, St. Peter's Park, London, N.W.
1892. §Grove, Mrs. Lilly, F.R.G.S. Mason College, Birmingham.
GROVE, The Right Hon. Sir WILLIAM ROBERT, Knt., M.A., D.C.L., LL.D., F.R.S. 115 Harley-street, London, W.
1891. ‡Grover, Henry Llewellin. Clydach Court, Pontypridd.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, Sir HOWARD, F.R.S., F.R.A.S. 51 Kenilworth-square, Rathgar, Dublin.
1886. ‡Grundy, John. 17 Private-road, Mapperley, Nottingham.
1891. ‡Grylls, W. London and Provincial Bank, Cardiff.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
1887. ‡GUILLEMARD, F. H. H. Eltham, Kent.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1885. ‡Gunn, John. 4 Parkside-terrace, Edinburgh.
1891. ‡Gunn, John. Llandaff House, Llandaff.
1877. ‡Gunn, William, F.G.S. Office of the Geological Survey of Scotland, Sheriff's Court House, Edinburgh.
1866. ‡GÜNTHER, ALBERT C. L. G., M.A., M.D., Ph.D., F.R.S., Keeper of the Zoological Collections in the British Museum. British Museum, South Kensington, London, S.W.
1880. §Guppy, John J. Ivy-place, High-street, Swansea.
1876. ‡Guthrie, Francis. Cape Town, Cape of Good Hope.
1883. ‡*Guthrie, Malcolm. 2 Parkfield-road, Liverpool.*
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.
1876. ‡GWYTHER, R. F., M.A. Owens College, Manchester.

1884. ‡Haanel, E., Ph.D. Cobourg, Ontario, Canada.
1887. ‡Hackett, Henry Eugene. Hyde-road, Gorton, Manchester.
1865. ‡*Hackney, William. 9 Victoria-chambers, Victoria-street, London, S.W.*
1884. ‡Hadden, Captain C. F., R.A. Woolwich.
1881. *HADDON, ALFRED CORT, B.A., F.Z.S., Professor of Zoology in the Royal College of Science, Dublin.
1842. Hadfield, George. Victoria-park, Manchester.
1888. *Hadfield, R. A. Hecla Works, Sheffield.
1892. §Haigh, E., M.A. Longton, Staffordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
1879. ‡HAKE, H. WILSON, Ph.D., F.C.S. Queenwood College, Hants.
1875. ‡Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1887. ‡Hale, The Hon. E. J. 9 Mount-street, Manchester.
1879. *Hall, Ebenezer. Abbeydale Park, near Sheffield.
1883. **Hall, Miss Emily. Burlington House, Spring Grove, Isleworth, Middlesex.*
1881. ‡Hall, Frederick Thomas, F.R.A.S. 15 Gray's Inn-square, London, W.C.
1854. *HALL, HUGH FERGIE, F.G.S. Staverton House, Woodstock-road, Oxford.
1887. ‡Hall, John. Springbank, Leftwich, Northwich.
1872. *Hall, Captain Marshall, F.G.S. Easterton Lodge, Parkstone R.S.O., Dorset.

Year of
Election.

1885. §Hall, Samuel. 19 Aberdeen Park, Highbury, London, N.
1884. ‡Hall, Thomas Proctor. School of Practical Science, Toronto, Canada.
1866. *HALL, TOWNSHEND M., F.G.S. Orchard House, Pilton, Barnstaple.
1891. *Hallett, George. Cranford, Victoria-road, Penarth, Glamorganshire.
1891. §Hallett, J. H., M.Inst.C.E. Maindy Lodge, Cardiff.
1873. *HALLETT, T. G. P., M.A. Claverton Lodge, Bath.
1888. §Halliburton, W. D., M.D., F.R.S., Professor of Physiology in King's College, London. 9 Ridgmount-gardens, Gower-street, London, W.C.
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1886. ‡*Hambleton, G. W. 23 Bryanston-street, Portman-square, London, W.*
1858. *Hambly, Charles Hambly Burbridge, F.G.S. Holmeside, Hazelwood, Derby.
1883. *Hamel, Egbert D. de. Middleton Hall, Tamworth.
1885. ‡Hamilton, David James. 1A Albyn-place, Aberdeen.
1869. ‡Hamilton, Rowland. Oriental Club, Hanover-square, London, W.
1888. *HAMMOND, ANTHONY, J.P. 10 Royal-crescent, Bath.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1881. *Hammond, Robert. Hilldrop, Highgate, London, N.
1892. ‡Hanbury, Thomas, F.L.S. La Mortola, Ventimiglia, Italy.
1878. ‡Hance, Edward M., LL.B. 15 Pelham-grove, Sefton Park, Liverpool.
1875. ‡Hancock, C. F., M.A. 125 Queen's-gate, London, S.W.
1861. ‡Hancock, Walter. 10 Upper Chadwell-street, Pentonville, London, E.C.
1876. ‡Hancock, Mrs. W. Neilson. 64 Upper Gardiner-street, Dublin.
1890. ‡Hankin, Ernest Hanbury. St. John's College, Cambridge.
1882. ‡Hankinson, R. C. Bassett, Southampton.
1884. §Hannaford, E. P. 2573 St. Catherine-street, Montreal, Canada.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1886. §Hansford, Charles. 3 Alexandra-terrace, Dorchester.
1859. *HARCOURT, A. G. VERNON, M.A., D.C.L., LL.D., F.R.S., F.C.S. (GENERAL SECRETARY.) Cowley Grange, Oxford.
1890. *HARCOURT, L. F. VERNON, M.Inst.C.E. 6 Queen Anne's-gate, London, S.W.
1886. *Hardcastle, Basil W., F.S.S. Beechenden, Hampstead, London, N.W.
1892. §Harden, Arthur, F.C.S. Ashville, Upper Chorlton-road, Manchester.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Millbrook House, Exeter.
1877. ‡Harding, Stephen. Bower Ashton, Clifton, Bristol.
1869. ‡Harding, William D. Islington Lodge, King's Lynn, Norfolk.
1886. ‡*Hardman, John B. St. John's, Hunter's-lane, Birmingham.*
1880. ‡*Hardy John.* 118 *Embden-road, Manchester.*
1838. *HARE, CHARLES JOHN, M.D. Berkeley House, 15 Manchester-square, London, W.
1858. ‡Hargrave, James. Burley, near Leeds.
1883. ‡Hargreaves, Miss H. M. 69 Alexandra-road, Southport.
1883. ‡Hargreaves, Thomas. 69 Alexandra-road, Southport.
1890. ‡Hargrove, Rev. Charles. 10 De Grey-terrace, Leeds.
1881. ‡Hargrove, William Wallace. St. Mary's, Bootham, York.
1890. §HARKER, ALFRED, M.A., F.G.S. St. John's College, Cambridge.
1876. ‡Harker, Allen, F.L.S., Professor of Natural History in the Royal Agricultural College, Cirencester.
1887. ‡Harker, T. H. Brook House, Fallowfield, Manchester.
1878. *Harkness, H. W. California Academy of Sciences, San Francisco, California, U.S.A.

Year of Election.

1871. ‡Harkness, William, F.C.S. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A., F.G.S., F.L.S., F.S.A. The Vicarage, Harefield, Middlesex.
1877. *Harland, Henry Seaton. 8 Arundel-terrace, Brighton, Sussex.
1883. *Harley, Miss Clara. The Quintic, Savile Park, Halifax, Yorkshire.
1862. *Harley, George, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
1883. *Harley, Harold. 14 Chapel-street, Bedford-row, London, W.C.
1862. *Harley, Rev. Robert, M.A., F.R.S., F.R.A.S. The Quintic, Savile Park, Halifax, Yorkshire.
1868. *Harmer, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1881. *Harmer, Sidney F., M.A., B.Sc. King's College, Cambridge.
1882. ‡Harper, G. T. Bryn Hyfrydd, Portswood, Southampton.
1872. ‡Harpley, Rev. William, M.A. Clayhanger Rectory, Tiverton.
1884. ‡Harrington, B. J., B.A., Ph.D., Professor of Chemistry and Mineralogy in McGill University, Montreal. Wallbrac-place, Montreal, Canada.
1872. *Harris, Alfred. Lunefield, Kirkby Lonsdale, Westmoreland.
1888. ‡Harris, C. T. 4 Kilburn Priory, London, N.W.
1842. *Harris, G. W., M.Inst.C.E. Moray-place, Dunedin, New Zealand.
1889. §Harris, H. Graham, M.Inst.C.E. 5 Great George-street, Westminster, S.W.
1884. ‡Harris, Miss Katherine E. 73 Albert Hall-mansions, Kensington-gore, London, S.W.
1888. ‡Harrison, Charles. 20 Lennox-gardens, London, S.W.
1860. ‡Harrison, Rev. Francis, M.A. North Wraxall, Chippenham.
1864. ‡Harrison, George. Barnsley, Yorkshire.
1874. ‡Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *Harrison, James Park, M.A. 22 Connaught-street, Hyde Park, London, W.
1892. ‡Harrison, John. Rockville, Napier-road, Edinburgh.
1889. §Harrison, J. C. Oxford House, Castle-road, Scarborough.
1870. ‡Harrison, Reginald, F.R.C.S. 6 Lower Berkeley-street, Portman-square, London, W.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1892. ‡Harrison, Rev. S. N. Ramsay, Isle of Man.
1886. ‡Harrison, W. Jerome, F.G.S. Board School, Icknield-street, Birmingham.
1885. ‡Hart, Charles J. 10 Calthorpe-road, Edgbaston, Birmingham.
1876. *Hart, Thomas. Brooklands, Blackburn.
1875. ‡Hart, W. E. Kilderry, near Londonderry.
1893. *Hartland, E. Sidney, F.S.A. Barnwood Court, Gloucester.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel, F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, Dublin.
1890. **Hartnell, Wilson.* 8 *Blenheim-terrace, Leeds.*
1886. *Hartog, Professor M. M., D.Sc. Queen's College, Cork.
1887. §Hartog, P. J., B.Sc. Owens College, Manchester.
1885. ‡*Harvey, Surgeon-Major Robert, M.D. Calcutta.*
1885. §Harvie-Brown, J. A. Dunipace, Larbert, N.B.
1862. *Harwood, John. Woodside Mills, Bolton-le-Moors.
1884. ‡Haslam, Rev. George, M.A. Trinity College, Toronto, Canada.
1882. ‡Haslam, George James, M.D. Owens College, Manchester.
1893. §Haslam, Lewis. Ravenswood, near Bolton, Lancashire.
1875. *Hastings, G. W. Barnard's Green House, Malvern.
1889. ‡Hatch, Dr. F. H., F.G.S. 28 Jermyn-street, London, S.W.

Year of Election.

1893. §Hatton, John L. S. People's Palace, Mile End-road, London, E.
1857. ‡HAUGHTON, Rev. SAMUEL, M.A., M.D., D.C.L., LL.D., F.R.S., M.R.I.A., F.G.S., Senior Fellow of Trinity College, Dublin. Trinity College, Dublin.
1887. *Hawkins, William. 11 Fountain-street, Manchester.
1872. *Hawkshaw, Henry Paul. 58 Jermyn-street, St. James's, London, S.W.
1864. *HAWKSHAW, JOHN CLARKE, M.A., M.Inst.C.E., F.G.S. 50 Harrington-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1884. *Haworth, Abraham. Hilston House, Altrincham.
1889. §Haworth, George C. Ordsal, Salford.
1887. *Haworth, Jesse. Woodside, Bowdon, Cheshire.
1887. ‡Haworth, S. E. Warsley-road, Swinton, Manchester.
1886. ‡Haworth, Rev. T. J. Albert Cottage, Saltley, Birmingham.
1890. ‡Hawtin, J. N. Sturdie House, Roundhay-road, Leeds.
1877. ‡Hay, Arthur J. Lerwick, Shetland.
1861. *HAY, Admiral the Right Hon. Sir JOHN C. D., Bart., K.C.B., D.C.L., F.R.S. 108 St. George's-square, London, S.W.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1885. *Haycraft, John Berry, M.D., B.Sc., F.R.S.E. University College, Cardiff.
1891. ‡Hayde, Rev. J. St. Peter's, Cardiff.
1873. *Hayes, Rev. William A., M.A. Dromore, Co. Down, Ireland.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A., F.R.S. Ashcombe, Shanklin, Isle of Wight.
1888. ‡Hazard, Rowland R. Little Mulgrave House, Hurlingham.
1851. §HEAD, JEREMIAH, M.Inst.C.E., F.C.S. 47 Queen-street, Westminster, S.W.
1883. ‡Headley, Frederick Halcombe. Manor House, Petersham, S.W.
1883. ‡Headley, Mrs. Marian. Manor House, Petersham, S.W.
1883. §Headley, Rev. Tanfield George. Manor House, Petersham, S.W.
1871. §Healey, George. Brantfield, Bowness, Windermere.
1883. *Heap, Ralph, jun. 1 Brick-court, Temple, London, E.C.
1861. *Heape, Benjamin. Northwood, Prestwich, Manchester.
1883. ‡Heape, Charles. Tovrak, Oxton, Cheshire.
1883. ‡Heape, Joseph R. 96 Tweedale-street, Rochdale.
1882. *Heape, Walter, M.A. St. Mary's, Trumpington, Cambridge.
1877. ‡Hearder, Henry Pollington. Westwell-street, Plymouth.
1877. ‡Hearder, William Keep, F.S.A. 195 Union-street, Plymouth.
1883. ‡Heath, Dr. 46 Hoghton-street, Southport.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1884. ‡Heath, Thomas, B.A. Royal Observatory, Calton Hill, Edinburgh.
1883. ‡Heaton, Charles. Marlborough House, Hesketh Park, Southport.
1886. ‡Heaton, Miss Ellen. Woodhouse-square, Leeds.
1865. ‡Heaton, Harry. Harborne House, Harborne, Birmingham.
1892. *HEATON, WILLIAM H., M.A., Professor of Physics in University College, Nottingham.
1889. *Heaviside, Arthur West. 7 Grafton-road, Whitley, Newcastle-upon-Tyne.
1884. §Heaviside, Rev. George, B.A., F.R.G.S., F.R.Hist.S. 7 Grosvenor-street, Coventry.
1833. ‡HEAVISIDE, Rev. Canon J. W. L., M.A. The Close, Norwich.
1888. *Heawood, Edward, B.A., F.G.S. 41 Old Elvet, Durham.
1888. *Heawood, Percy Y., Lecturer in Mathematics at Durham University. 41 Old Elvet, Durham.

Year of Election.

1855. ‡HECTOR, Sir JAMES, K.C.M.G., M.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡Heddle, M. Forster, M.D., F.R.S.E. St. Andrews, N.B.
1869. ‡*Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.*
1882. ‡Hedger, Philip. Cumberland-place, Southampton.
1887. *HEDGES, KILLINGWORTH, M.Inst.C.E. 7 Carteret-street, London, S.W.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-upon-Tyne.
1881. *HELE-SHAW, H. S., M.Inst.C.E., Professor of Engineering in University College, Liverpool. 20 Waverley-road, Liverpool.
1887. §Hembry, Frederick William, F.R.M.S. Sussex Lodge, Sidcup, Kent.
1867. ‡Henderson, Alexander. Dundee.
1873. *Henderson, A. L. 277 Lewisham High-road, London, S.E.
1883. ‡Henderson, Mrs. A. L. 277 Lewisham High-road, London, S.E.
1891. *Henderson, G. G., D.Sc., M.A., F.C.S., F.I.C., Professor of Chemistry in the Glasgow and West of Scotland Technical College. 204 George-street, Glasgow.
1892. §Henderson, John. 3 St. Catherine-place, Grange, Edinburgh.
1880. *Henderson, Captain W. H., R.N. 21 Albert Hall-mansions, London, S.W.
1885. ‡Henderson, Sir William. Devanha House, Aberdeen.
1892. §Henigan, Richard. Alma-road, The Avenue, Southampton.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A. 81 Marlborough-road, Dublin.
1873. *HENRICI, OLAUS M. F. E., Ph.D., F.R.S., Professor of Mechanics and Mathematics in the City and Guilds of London Institute. Central Institution, Exhibition-road, London, S.W. 34 Clarendon-road, Notting Hill, W.

Henry, Franklin. Portland-street, Manchester.

Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.

Henry, Mitchell. Stratheden House, Hyde Park, London, W.

1884. ‡Henshaw, George H. 43 Victoria-street, Montreal, Canada.
1892. ‡Hepburn, David, M.D., F.R.S.E. The University, Edinburgh.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Dartford, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
1890. ‡Hepper, J. 43 Cardigan-road, Headingley, Leeds.
1890. ‡Hepworth, Joseph. 25 Wellington-street, Leeds.
1892. *Herbertson, Andrew J. University Hall, Edinburgh.
1887. *HERDMAN, WILLIAM A., D.Sc., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in University College, Liverpool.
1891. ‡Hern, S. South Cliff, Marine Parade, Penarth.
1871. *HERSCHEL, ALEXANDER S., M.A., D.C.L., F.R.S., F.R.A.S., Honorary Professor of Physics and Experimental Philosophy in the University of Durham College of Science, Newcastle-upon-Tyne. Observatory House, Slough, Bucks.
1874. §HERSCHEL, Colonel JOHN, R.E., F.R.S., F.R.A.S. Observatory House, Slough, Bucks.
1890. ‡Hewetson, H. Bendelack, M.R.C.S., F.L.S. 11 Hanover-square, Leeds.
1884. §Hewett, George Edwin. Cotswold House, St. John's Wood Park, London, N.W.
1893. §Hewitt, Thomas P. Eccleston Park, Prescot, Lancashire.
1883. ‡Hewson, Thomas. Care of J. C. C. Payne, Esq., Botanic-avenue, The Plains, Belfast.
1881. ‡Hey, Rev. William Croser, M.A. Clifton, York.
1882. ‡Heycock, Charles T., B.A. King's College, Cambridge.

Year of Election.

1883. ‡Heyes, Rev. John Frederick, M.A., F.C.S., F.R.G.S. 3 Beaconsfield-villas, Dynham-road, West Hampstead, London, N.W.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1879. ‡Heywood, A. Percival. Duffield Bank, Derby.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
1886. §Heywood, Henry, J.P., F.C.S. Witla Court, near Cardiff.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1887. ‡Heywood, Robert. Mayfield, Victoria Park, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.
1888. ‡Hichens, James Harvey, M.A., F.G.S. The College, Cheltenham.
1881. §Hick, Thomas, B.A., B.Sc. Brighton Grove, Rusholme, Manchester.
1875. ‡Hicks, Henry, M.D., F.R.S., F.G.S. Hendon Grove, Hendon, Middlesex, N.W.
1877. §Hicks, Professor W. M., M.A., D.Sc., F.R.S., Principal of Firth College, Sheffield. Firth College, Sheffield.
1886. ‡Hicks, Mrs. W. M. Dunheved, Endcliffe-crescent, Sheffield.
1884. ‡Hickson, Joseph. 272 Mountain-street, Montreal, Canada.
1887. *Hickson, Sydney J., M.A., D.Sc. Downing College, Cambridge.
1864. *Hiern, W. P., M.A. Castle House, Barnstaple.
1875. ‡Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡Higgins, Clement, B.A., F.C.S. 103 Holland-road, Kensington, London, W.
1891. §Higgs, Henry, LL.B., F.S.S. 164 Brixton Hill, London, S.W.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
1885. *Hill, Alexander, M.A., M.D. Downing College, Cambridge.
Hill, Arthur. Bruce Castle, Tottenham, Middlesex.
1872. §Hill, Charles, F.S.A. Rockhurst, West Hoathly, East Grinstead.
*Hill, Rev. Canon Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1881. *Hill, Rev. Edwin, M.A., F.G.S. The Rectory, Cockfield, R.S.O., Suffolk.
1887. ‡Hill, G. H. Albert-chambers, Albert-square, Manchester.
1884. ‡Hill, Rev. James Edgar, M.A., B.D. 2488 St. Catherine-street, Montreal, Canada.
1857. §Hill, John, M.Inst.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1886. ‡Hill, M. J. M., M.A., D.Sc., Professor of Pure Mathematics in University College, London.
1881. ‡Hill, Pearson. 50 Belsize Park, London, N.W.
1885. *Hill, Sidney. Langford House, Langford, Bristol.
1888. ‡Hill, William. Hitchin, Herts.
1876. ‡Hill, William H. Barlanark, Shettleston, N.B.
1885. *Hillhouse, William, M.A., F.L.S., Professor of Botany in Mason Science College, Birmingham. 95 Harborne-road, Edgbaston, Birmingham.
1886. §Hillier, Rev. E. J. Cardington Vicarage, Bedford.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1887. ‡Hilton, Edwin. Oak Bank, Fallowfield, Manchester.
1858. ‡Hincks, Rev. Thomas, B.A., F.R.S. Stokeleigh, Leigh Woods, Clifton, Bristol.
1870. ‡Hinde, G. J., Ph.D., F.G.S. Avondale-road, Croydon, Surrey.
1883. *Hindle, James Henry. 8 Cobham-street, Accrington.
1888. *Hindmarsh, William Thomas, F.L.S. Alnbank, Alnwick.
1886. ‡Hingley, Sir Benjamin, Bart., M.P. Hatherton Lodge, Cradley, Worcestershire.

Year of Election.

1881. ‡Hingston, J. T. Clifton, York.
1884. ‡HINGSTON, WILLIAM HALES, M.D., D.C.L. 37 Union-avenue, Montreal, Canada.
1884. ‡Hirschfilder, C. A. Toronto, Canada.
1890. *Hirst, James Andus. Adel Tower, Leeds.
1858. ‡Hirst, John, jun. Dobcross, near Manchester.
1884. ‡Hoadrey, John Chipman. Boston, Massachusetts, U.S.A.
Hoare, J. Gurney. Hampstead, London, N.W.
1881. §Hobbes, Robert George. Livingstone House, 374 Wandsworth-road London, S.W.
1879. ‡Hobkirk, Charles P., F.L.S. West Riding Union Bank, Dewsbury.
1887. *Hobson, Bernard, B.Sc. Tapton Elms, Sheffield.
1883. ‡Hobson, Rev. E. W. 55 Albert-road, Southport.
1877. ‡Hockin, Edward. Poughill, Stratton, Cornwall.
1883. ‡Hocking, Rev. Silas K. 21 Scarisbrick New-road, Southport.
1877. ‡Hodge, Rev. John Mackey, M.A. 38 Tavistock-place, Plymouth.
1876. ‡Hodges, Frederick W. Queen's College, Belfast.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS, B.A., D.C.L. Benwell Dene, Newcastle-upon-Tyne.
1887. *Hodgkinson, Alexander, M.B., B.Sc., Lecturer on Laryngology at Owens College, Manchester. 18 St. John-street, Manchester.
1880. §Hodgkinson, W. R. Eaton, Ph.D., F.R.S.E., Professor of Chemistry and Physics in the Royal Artillery College, Woolwich. 8 Park-villas, Blackheath, London, S.E.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1884. ‡Hodgson, Jonathan. Montreal, Canada.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. 7 Sandhill, Newcastle-upon-Tyne.
1854. *Holcroft, George. Tyddyngwladis, Ganllwyd, near Dolgelly, North Wales.
1883. ‡Holden, Edward. Laurel Mount, Shipley, Yorkshire.
1873. *Holden, Sir Isaac, Bart., M.P. Oakworth House, near Keighley, Yorkshire.
1883. ‡Holden, James. 12 Park-avenue, Southport.
1883. ‡Holden, John J. 23 Duke-street, Southport.
1884. ‡Holden, Mrs. Mary E. Dunham Ladies' College, Quebec, Canada.
1857. *Holder, Henry William, M.A. Owens College, Manchester.
1887. *Holdsworth, C. J. Hill Top, near Kendal, Westmoreland.
1891. ‡Holgate, Benjamin, F.G.S. Cardigan Villa, Grove-lane, Headingley, Leeds.
1879. ‡Holland, Calvert Bernard. Ebbw Vale, South Wales.
*Holland, Philip H. 3 Heath-rise, Willow-road, Hampstead, London, N.W.
1889. §Holländer, Bernard. King's College, Strand, London, W.C.
1886. ‡Holliday, J. R. 101 Harborne-road, Birmingham.
1865. ‡Holliday, William. New-street, Birmingham.
1883. ‡Hollingsworth, Dr. T. S. Elford Lodge, Spring Grove, Isleworth, Middlesex.
1883. *Holmes, Mrs. Basil. 5 Freeland-road, Ealing, Middlesex, W.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡*Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.*
1892. ‡Holmes, Matthew. Netherby, Lenzie, Scotland.
1889. ‡*Holmes, Ralph, B.A. Hulme Grammar School, Manchester.*
1882. *Holmes, Thomas Vincent, F.G.S. 28 Croom's-hill, Greenwich, S.E.
1893. *Holt, Miss J. B. Crofton, Aigburth, Liverpool.
1891. *Hood, Archibald, M.Inst.C.E. 42 Newport-road, Cardiff.

Year of Election.

1875. *Hood, John. Chesterton, Cirencester.
1847. ‡HOOKER, Sir JOSEPH DALTON, K.C.S.I., C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., F.R.G.S. The Camp, Sunningdale.
1892. §Hooker, Reginald H., B.A. Royal Statistical Society, 9 Adelphi-terrace, London, W.C.
1865. *Hooper, John P. Coventry Park, Streatham, London, S.W.
1877. *Hooper, Rev. Samuel F., M.A. The Vicarage, Blackheath Hill, Greenwich, S.E.
1856. ‡Hooton, Jonathan. 116 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. 14 Airlie-gardens, Campden Hill, London, W.
1884. *Hopkins, Edward M. Orchard Dene, Henley-on-Thames.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1884. *HOPKINSON, CHARLES. 305 Moss-lane East, Manchester.
1882. *Hopkinson, Edward, M.A., D.Sc. Oakleigh, Timperley, Cheshire.
1870. *HOPKINSON, JOHN, M.A., D.Sc., F.R.S. Holmwood, Wimbledon, Surrey.
1871. *HOPKINSON, JOHN, F.L.S., F.G.S., F.R.Met.Soc. 34 Margaret-street, Cavendish-square, London, W.; and The Grange, St. Albans.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
1891. ‡Horder, T. Garrett. 29 Charles-street, Cardiff.
Hornby, Hugh. Sandown, Liverpool.
1886. ‡Horne, Edward H. Innisfail, Beulah Hill, Norwood, S.E.
1885. ‡Horne, John, F.R.S.E., F.G.S. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1876. *Horne, Robert R. 150 Hope-street, Glasgow.
1875. *Horniman, F. J., F.R.G.S., F.L.S. Surrey Mount, Forest Hill, London, S.E.
1884. *Horsfall, Richard. Stoodley House, Halifax.
1887. ‡Horsfall, T. C. Swanscoe Park, near Macclesfield.
1892. ‡Horsley, Reginald E., M.B. 46 Heriot-row, Edinburgh.
1893. *HORSLEY, VICTOR A. H., B.Sc., F.R.S., F.R.C.S., Professor of Pathology in University College, London. 25 Cavendish-square, London, W.
1884. *Hotblack, G. S. Prince of Wales-road, Norwich.
1868. ‡*Hotson, W. C. Upper King-street, Norwich.*
1859. ‡Hough, Joseph, M.A., F.R.A.S. Codsall Wood, Wolverhampton.
1886. ‡Houghton, F. T. S., M.A. 119 Gough-road, Edgbaston, Birmingham.
1887. ‡Houldsworth, Sir W. H., Bart., M.P. Norbury Booths, Knutsford.
1884. ‡Houston, William. Legislative Library, Toronto, Canada.
1883. *Hovenden, Frederick, F.L.S., F.G.S. Glenlea, Thurlow Park-road, West Dulwich, Surrey, S.E.
Hovenden, W. F., M.A. Bath.
1893. §Howard, F. T., B.A., F.G.S. University College, Cardiff.
1883. ‡Howard, James Fielden, M.D., M.R.C.S. Sandycroft, Shaw.
1886. *Howard, James L., D.Sc. 20 Oxford-road, Waterloo, near Liverpool.
1887. *Howard, S. S. Llanishen Rise, near Cardiff.
1882. ‡Howard, William Frederick, Assoc.M.Inst.C.E. 13 Cavendish-street, Chesterfield, Derbyshire.
1886. ‡Howatt, David. 3 Birmingham-road, Dudley.
1876. ‡Howatt, James. 146 Buchanan-street, Glasgow.
1885. ‡Howden, James C., M.D. Sunnyside, Montrose, N.B.
1889. §Howden, Robert, M.B. University of Durham College of Medicine, Newcastle-upon-Tyne.
1857. ‡Howell, Henry H., F.G.S., Director of the Geological Survey of Great Britain. Geological Survey Office, Edinburgh.

Year of Election.

1887. ‡*Howell, J. A. Edward-street, Werneth, Oldham.*
1868. ‡HOWELL, Rev. Canon HINDS. Drayton Rectory, near Norwich.
1891. §Howell, Rev. William Charles, M.A., Vicar of Holy Trinity, High Cross, Tottenham, Middlesex.
1886. §HOWES, Professor G. B., F.L.S. Royal College of Science, South Kensington, London, S.W.
1884. ‡Howland, Edward P., M.D. 211 41½-street, Washington, U.S.A.
1884. ‡Howland, Oliver Aiken. Toronto, Canada.
1865. *HOWLETT, Rev. FREDERICK, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡HOWORTH, Sir H. H., K.C.I.E., M.P., F.R.S., F.S.A. Bentcliffe, Eccles, Manchester.
1883. ‡Howorth, John, J.P. Springbank, Burnley, Lancashire.
1883. ‡Hoyle, James. Blackburn.
1887. §HOYLE, WILLIAM E., M.A. Owens College, Manchester.
1888. ‡Hudd, Alfred E., F.S.A. 94 Pembroke-road, Clifton, Bristol.
1888. ‡Hudson, C. T., M.A., LL.D., F.R.S. 2 Barton-crescent, Dawlish.
1867. *HUDSON, WILLIAM H. H., M.A., Professor of Mathematics in King's College, London. 15 Altenberg-gardens, Clapham Common, London, S.W.
1858. *HUGGINS, WILLIAM, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. 90 Upper Tulse Hill, Brixton, London, S.W.
1892. ‡Hughes, Alfred W. Woodside, Musselburgh.
1887. ‡Hughes, E. G. 4 Roman-place, Higher Broughton, Manchester.
1883. ‡Hughes, Miss E. P. Newnham College, Cambridge.
1871. *Hughes, George Pringle, J.P. Middleton Hall, Wooler, Northumberland.
1887. ‡Hughes, John Taylor. Thorleymoor, Ashley-road, Altrincham.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.
1891. §Hughes, Thomas. 31 Loudoun-square, Cardiff.
1876. *Hughes, Rev. Thomas Edward. Wallfield House, Reigate.
1868. §HUGHES, T. M'K., M.A., F.R.S., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1891. §Hughes, Rev. W. Hawker. Jesus College, Oxford.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
1883. ‡HULKE, JOHN WHITAKER, F.R.S., F.R.C.S., F.G.S. 10 Old Burlington-street, London, W.
1867. §HULL, EDWARD, M.A., LL.D., F.R.S., F.G.S. 20 Arundel-gardens, Notting Hill, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1887. *HUMMEL, Professor J. J. Yorkshire College, Leeds.
1890. ‡Humphrey, Frank W. 63 Prince's-gate, London, S.W.
1884. *Humphreys, A. W. 50 Broadway, New York, U.S.A.
1878. ‡Humphreys, H. Castle-square, Carnarvon.
1880. ‡Humphreys, Noel A., F.S.S. Ravenhurst, Hook, Kingston-on-Thames.
1862. *HUMPHRY, Sir GEORGE MURRAY, M.D., F.R.S., Professor of Surgery in the University of Cambridge. Grove Lodge, Cambridge.
1877. *HUNT, ARTHUR ROOPE, M.A., F.G.S. Southwood, Torquay.
1891. *Hunt, Cecil Arthur. Southwood, Torquay.
1886. ‡Hunt, Charles. The Gas Works, Windsor-street, Birmingham.
1891. ‡Hunt, D. de Vere, M.D. Westbourne-crescent, Sophia-gardens, Cardiff.
1865. ‡*Hunt, J. P. Gospel Oak Works, Tipton.*

Year of Election

1864. ‡*Hunt, W.* *Folkestone.*
1875. *Hunt, William. Northcote, Westbury-on-Trym, Bristol.
1881. ‡Hunter, F. W. Newbottle, Fence Houses, Co. Durham.
1889. ‡Hunter, Mrs. F. W. Newbottle, Fence Houses, Co. Durham.
1881. ‡Hunter, Rev. John. University-gardens, Glasgow.
1884. *Hunter, Michael. Greystones, Sheffield.
1869. *Hunter, Rev. Robert, LL.D., F.G.S. Forest Retreat, Staples-road, Loughton, Essex.
1879. ‡HUNTINGTON, A. K., F.C.S., Professor of Metallurgy in King's College, London. King's College, London, W.C.
1885. ‡Huntly, The Most Hon. the Marquess of. Aboyne Castle, Aberdeenshire.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1883. *Hurst, Charles Herbert. Owens College, Manchester.
1869. ‡Hurst, George. Bedford.
1882. ‡Hurst, Walter, B.Sc. West Lodge, Todmorden.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
1887. ‡Husband, W. E. 56 Bury New-road, Manchester.
1882. ‡Hussey, Captain E. R., R.E. 24 Waterloo-place, Southampton.
1876. ‡*Hutchinson, John.* 22 *Hamilton Park-terrace, Glasgow.*
1868. *Hutchison, Robert, F.R.S.E. Barnhill, Brodick, Isle of Arran, N.B.
Hutton, Crompton. Harescombe Grange, Stroud, Gloucestershire.
1864. *Hutton, Darnton. 14 Cumberland-terrace, Regent's Park, London, N.W.
1857. ‡*Hutton, Henry D.* 17 *Palmerston-road, Dublin.*
1887. *Hutton, J. Arthur. 29 Dale-street, Manchester.
1861. *HUTTON, T. MAXWELL. Summerhill, Dublin.
1852. ‡HUXLEY, The Right Hon. THOMAS HENRY, Ph.D., LL.D., D.C.L., F.R.S., F.L.S., F.G.S., Hon. Professor of Biology in the Royal College of Science, London. Hodeslea, Eastbourne.
Hyde, Edward. Dukinfield, near Manchester.
1883. ‡Hyde, George H. 23 Arbour-street, Southport.
1871. *Hyett, Francis A. Painswick House, Stroud, Gloucestershire.

1882. *I'Anson, James, F.G.S. Fairfield House, Darlington.
1883. §Idris, T. H. W. 58 Lady Margaret-road, London, N.W.
Ihne, William, Ph.D. Heidelberg.
1884. *Iles, George. 7 Brunswick-street, Montreal, Canada.
1885. ‡im-Thurn, Everard F., C.M.G., M.A. British Guiana.
1888. *Ince, Surgeon-Lieut.-Col. John, M.D. Montague House, Swanley, Kent.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1893. §Ingle, Herbert. Pool, Leeds.
1876. ‡Inglis, John, jun. Prince's-terrace, Dowanhill, Glasgow.
1891. ‡Ingram, Lieut.-Colonel C. W. Bradford-place, Penarth.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Senior Lecturer in the University of Dublin. 2 Wellington-road, Dublin.
1885. ‡Ingram, William, M.A. Gamrie, Banff.
1886. ‡Innes, John. The Limes, Alcester-road, Moseley, Birmingham.
1892. §Ireland, D. W. 10 South Gray-street, Edinburgh.
1892. ‡Irvine, James. Devonshire-road, Birkenhead.
1892. ‡Irvine, Robert, F.R.S.E. Royston, Granton, Edinburgh.
1882. §IRVING, Rev. A., B.A., D.Sc., F.G.S. Hockerill, Bishop Stortford, Herts.

Year of Election.

1888. *Isaac, J. F. V., B.A. 114 Marine-parade, Brighton.
1883. ‡Isherwood, James. 18 York-road, Birkdale, Southport.
1881. ‡Ishiguro, Isoji. Care of the Japanese Legation, 9 Cavendish-square, London, W.
1891. *Ismay, Thomas H. 10 Water-street, Liverpool.
1886. ‡Izod, William. Church-road, Edgbaston, Birmingham.

1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1884. ‡Jack, Peter. People's Bank, Halifax, Nova Scotia, Canada.
1876. *Jack, William, LL.D., Professor of Mathematics in the University of Glasgow. 10 The College, Glasgow.
1883. *JACKSON, Professor A. H., B.Sc., F.C.S. Care of Messrs. Wm. Bowen & Co., 358 Collins-street, Melbourne, Australia.
1879. ‡Jackson, Arthur, F.R.C.S. Wilkinson-street, Sheffield.
1883. ‡Jackson, Frank. 11 Park-crescent, Southport.
1883. *Jackson, F. J. 1 Morley-road, Southport.
1883. ‡Jackson, Mrs. F. J. 1 Morley-road, Southport.
1874. *Jackson, Frederick Arthur. Belmont, Lyme Regis, Dorset.
1886. §Jackson, George. Clareen, Higher Warberry, Torquay.
1887. *Jackson, George. 53 Elizabeth-street, Cheetham, Manchester.
1885. ‡Jackson, Henry. 19 Golden-square, Aberdeen.
1866. ‡Jackson, H. W., F.R.A.S. 67 Upgate, Louth, Lincolnshire.
1869. §Jackson, Moses, J.P. Lansdowne House, Tonbridge.
1887. §Jacobson, Nathaniel. Olive Mount, Cheetham Hill-road, Manchester.
1874. *Jaffe, John. 38 Prom. des Anglais, Nice, France.
1865. *Jaffray, Sir John, Bart. Park-grove, Edgbaston, Birmingham.
1891. ‡James, Arthur P. Grove House, Park-grove, Cardiff.
1891. *James, Charles Henry. 8 Courtland-terrace, Merthyr Tydfil.
1891. *James, Charles Russell. Brynteg, Merthyr Tydfil.
1872. ‡*James, Christopher. 8 Laurence Pountney-hill, London, E.C.*
1860. ‡James, Edward H. Woodside, Plymouth.
1886. ‡James, Frank. Portland House, Aldridge, near Walsall.
1891. ‡James, Ivor. University College, Cardiff.
1891. ‡James, John. 24 The Parade, Cardiff.
1891. ‡James, John Herbert. Howard House, Arundel-street, Strand, London, W.C.
1891. ‡James, J. R., L.R.C.P. 158 Cowbridge-road, Canton, Cardiff.
1858. ‡James, William C. Woodside, Plymouth.
1884. ‡Jameson, W. C. 48 Baker-street, Portman-square, London, W.
1881. ‡Jamieson, Andrew, Principal of the College of Science and Arts, Glasgow.
1887. §Jamieson, G. Auldjo. 37 Drumsheugh-gardens, Edinburgh.
1885. ‡Jamieson, Patrick. Peterhead, N.B.
1885. ‡Jamieson, Thomas. 173 Union-street, Aberdeen.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1889. *JAPP, F. R., M.A., LL.D., F.R.S., F.C.S., Professor of Chemistry in the University of Aberdeen.
1870. ‡Jarrold, John James. London-street, Norwich.
1891. ‡Jasper, Henry. Holmedale, New Park-road, Clapham Park, London, S.W.
1886. §Jeffcock, Rev. Prebendary John Thomas, F.S.A. The Rectory, Wolverhampton.
1891. ‡Jefferies, Henry. Plas Newydd, Park-road, Penarth.
1855. *Jeffray, John. 9 Winton-drive, Kelvinside, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F.R.A.S. Pump-court, Temple, London, E.C.

Year of Election.

1885. ‡Jeffreys, Dr. Richard Parker. Eastwood House, Chesterfield.
1887. §JEFFS, OSMUND W. 12 Queen's-road, Rock Ferry, Cheshire.
1881. ‡JELLICOE, C. W. A. Southampton.
1864. ‡Jelly, Dr. W. Aveleanas, 11, Valencia, Spain.
1873. §Jenkins, Major-General J. J. 16 St. James's-square, London, S.W.
1880. *JENKINS, Sir JOHN JONES. The Grange, Swansea.
1891. §Jenkins, Henry C., Assoc.M.Inst.C.E., F.C.S. 17 St. Julian's-road, Kilburn, London, N.W.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1893. §Jennings, G. E. Ash Leigh-road, Leicester.
1872. ‡Jennings, W. 13 Victoria-street, London, S.W.
1878. ‡Jephson, Henry L. Chief Secretary's Office, The Castle, Dublin.
Jessop, William, jun. Overton Hall, Ashover, Chesterfield.
1889. ‡Jevons, F. B., M.A. The Castle, Durham.
1884. ‡Jewell, Lieutenant Theo. F. Torpedo Station, Newport, Rhode Island, U.S.A.
1891. ‡John, E. Cowbridge, Cardiff.
1884. ‡Johns, Thomas W. Yarmouth, Nova Scotia, Canada.
1884. §Johnson, Alexander, M.A., LL.D., Professor of Mathematics in McGill University, Montreal. 5 Prince of Wales-terrace, Montreal, Canada.
1883. ‡Johnson, Miss Alice. Llandaff House, Cambridge.
1883. ‡Johnson, Ben. Micklegate, York.
1871. *Johnson, David, F.C.S., F.G.S. 3 Victoria-road, Clapham, London, S.W.
1883. ‡Johnson, Edmund Litler. 73 Albert-road, Southport.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1888. ‡Johnson, J. G. Southwood Court, Highgate, London, N.
1875. ‡Johnson, James Henry, F.G.S. 73 Albert-road, Southport.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1870. ‡Johnson, Richard C., F.R.A.S. 46 Jermyn-street, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1881. ‡Johnson, Sir Samuel George. Municipal Offices, Nottingham.
1890. *Johnson, Thomas, D.Sc., F.L.S., Professor of Botany in the Royal College of Science, Dublin.
1887. ‡Johnson, W. H. Woodleigh, Altrincham, Cheshire.
1883. ‡Johnson, W. H. F. Llandaff House, Cambridge.
1883. ‡Johnson, William. Harewood, Roe-lane, Southport.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham, Cheshire.
1883. ‡Johnston, H. H. Tudor House, Champion Hill, London, S.E.
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
1884. ‡Johnston, John L. 27 St. Peter-street, Montreal, Canada.
1883. ‡Johnston, Thomas. Broomsleigh, Seal, Sevenoaks.
1884. ‡Johnston, Walter R. Fort Qu'Appelle, N.W. Territory, Canada.
1884. *Johnston, W. H. 6 Latham-street, Preston, Lancashire.
1885. ‡JOHNSTON-LAVIS, H. J., M.D., F.G.S. Palazzo Caramanico, Chiatomone, Naples.
1886. ‡Johnstone, G. H. Northampton-street, Birmingham.
1864. *Johnstone, James. Alva House, Alva, by Stirling, N.B.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. ‡JOLLY, WILLIAM, F.R.S.E., F.G.S., H.M. Inspector of Schools. St. Andrew's-road, Pollokshields, Glasgow.
1888. ‡Jolly, W. C. Home Lea, Lansdowne, Bath.

Year of Election.

1888. ‡Joly, John, M.A., D.Sc., F.R.S. 39 Waterloo-road, Dublin.
1881. ‡Jones, Alfred Orlando, M.D. Cardigan Villa, Harrogate.
1849. ‡Jones, Baynham. Walmer House, Cheltenham.
1887. ‡Jones, D. E., B.Sc., H.M. Inspector of Schools.
1891. ‡Jones, D. Edgar, M.D. Spring Bank, Queen-street, Cardiff.
1890. §Jones, Rev. Edward, F.G.S. Osbourne-place, Fairfax-road, Prestwich, Lancashire.
1891. ‡Jones, Dr. Evan. Aberdare.
1891. ‡*Jones, Evan Rowland. Bonnyrigg, Penarth.*
1887. ‡Jones, Francis, F.R.S.E., F.C.S. Beaufort House, Alexandra Park, Manchester.
1891. *Jones, Rev. G. Hartwell, M.A. Nutfield Rectory, Redhill, Surrey.
1883. *Jones, George Oliver, M.A. 5 Cook-street, Liverpool.
1884. ‡Jones, Rev. Harry, M.A. 8 York-gate, Regent's Park, London, N.W.
1877. ‡Jones, Henry C., F.C.S. Royal College of Science, South Kensington, London, S.W.
1893. §Jones, Professor J. E., B.Sc. Ellenslea, 70 Lichfield-road, Stafford.
1881. *JONES, J. VIRIAMU, M.A., B.Sc., Principal of the University College of South Wales and Monmouthshire, Cardiff.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1880. ‡Jones, Thomas. 15 Gower-street, Swansea.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S. 10 Uverdale-road, King's-road, Chelsea, London, S.W.
1883. ‡Jones, William. Elsinore, Birkdale, Southport.
1891. ‡Jones, William Lester. 22 Newport-road, Cardiff.
1875. *Jose, J. E. 11 Cressington Park, Liverpool.
1884. ‡Joseph, J. H. 738 Dorchester-street, Montreal, Canada.
1891. ‡Jotham, F. H. Penarth.
1891. ‡Jotham, T. W. Penylan, Cardiff.
1875. *Joule, Benjamin St. John B., J.P. Rothesay, N.B.
1879. ‡Jowitt, A. Hawthorn Lodge, Clarkehouse-road, Sheffield.
1890. ‡Jowitt, Benson R. Elmhurst, Newton-road, Leeds.
1872. ‡Joy, Algernon. Junior United Service Club, St. James's, London, S.W.
1848. *Joy, Rev. Charles Ashfield. West Hanney, Wantage, Berkshire.
1883. ‡Joyce, Rev. A. G., B.A. St. John's Croft, Winchester.
1886. ‡Joyce, The Hon. Mrs. St. John's Croft, Winchester.
1891. ‡Joynes, John J. Great Western Colliery, near Coleford, Gloucestershire.
1848. *Jubb, Abraham. Halifax.
1870. ‡JUDD, JOHN WESLEY, F.R.S., F.G.S., Professor of Geology in the Royal College of Science, London. 16 Cumberland-road, Kew.
1883. ‡Justice, Philip M. 14 Southampton-buildings, Chancery-lane, London, W.C.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-road, London, N.
1888. §Kapp, Gisbert, M.Inst.C.E., M.Inst.E.E. Erba, Wimbledon Park, Surrey.
1887. ‡Kay, Miss. Hamerlaund, Broughton Park, Manchester.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
1883. ‡*Kearne, John H. Westcliffe-road, Birkdale, Southport.*
1884. ‡Keefer, Samuel. Brockville, Ontario, Canada.
1884. ‡Keefer, Thomas Alexander. Port Arthur, Ontario, Canada.

Year of Election.

1875. ‡Keeling, George William. Tuthill, Lydney.
1886. ‡Keen, Arthur, J.P. Sandyford, Augustus-road, Birmingham.
1892. ‡Keiller, Alexander, M.D., LL.D., F.R.S.E. 54 Northumberland-street, Edinburgh.
1887. ‡Kellas-Johnstone, J. F. 35 Crescent, Salford.
1884. ‡Kellogg, J. H., M D. Battle Creek, Michigan, U.S.A.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1885. §Keltie, J. Scott, Assist.Sec.R.G.S., F.S.S. 1 Savile-row, London, W.
1847. *Kelvin, The Right Hon. Lord, M.A., LL.D., D.C.L., Pres.R.S., F.R.S.E., F.R.A.S., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1877. *Kelvin, Lady. The University, Glasgow.
1887. §Kemp, Harry. 254 Stretford-road, Manchester.
1884. ‡Kemper, Andrew C., A.M., M.D. 101 Broadway, Cincinnati, U.S.A.
1890. §Kempson, Augustus. Care of Capital and Counties Bank, Northampton.
1891. §Kendall, Percy F., F.G.S. Yorkshire College, Leeds.
1875. ‡Kennedy, Alexander B. W., F.R.S., M.Inst.C.E., Emeritus Professor of Engineering in University College, London. 2 Gloucester-place, Portman-square, London, W.
1884. ‡Kennedy, George L., M.A., F.G.S., Professor of Chemistry and Geology in King's College, Windsor, Nova Scotia, Canada.
1876. ‡Kennedy, Hugh. 20 Mirkland-street, Glasgow.
1884. ‡Kennedy, John. 113 University-street, Montreal, Canada.
1884. ‡Kennedy, William. Hamilton, Ontario, Canada.
1886. ‡Kenrick, George Hamilton. Whetstone, Somerset-road, Edgbaston, Birmingham.
1893. §Kent, A. F. Stanley. St. Thomas's Hospital, London, S.E.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1886. §Kenward, James, F.S.A. 280 Hagley-road, Birmingham.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1876. ‡Ker, William. 1 Windsor-terrace West, Glasgow.
1881. ‡Kermode, Philip M. C. Ramsay, Isle of Man.
1892. §Kerr, J. Graham. Christ's College, Cambridge.
1884. ‡Kerr, James, M.D. Winnipeg, Canada.
1887. ‡Kerr, James. Dunkenhalgh, Accrington.
1883. ‡Kerr, Rev. John, LL.D., F.R.S. Free Church Training College, Glasgow.
1889. ‡Kerry, W. H. R. Wheatlands, Windermere.
1887. ‡Kershaw, James. Holly House, Bury New-road, Manchester.
1869. *Kesselmeyer, Charles A. Villa 'Mon Repos,' Altrincham, Cheshire.
1869. *Kesselmeyer, William Johannes. Villa 'Mon Repos,' Altrincham, Cheshire.
1883. *Keynes, J. N., M.A., D.Sc., F.S.S. 6 Harvey-road, Cambridge.
1876. ‡Kidston, J. B. 50 West Regent-street, Glasgow.
1886. §Kidston, Robert, F.R.S.E., F.G.S. 24 Victoria-place, Stirling.
1885. *Kilgour, Alexander. Loirston House, Cove, near Aberdeen.
1890. §Kimmins, C. W., M.A., D.Sc. Downing College, Cambridge.
1878. ‡Kinahan, Sir Edward Hudson, Bart. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. *Kinch, Edward, F.C.S. Royal Agricultural College, Cirencester.
1888. ‡King, Austin J. Winsley Hill, Limpley Stoke, Bath.
1888. *King, E. Powell. Wainsford, Lymington, Hants.
1883. *King, Francis. Alabama, Penrith.

Year of
Election.
1875. *King, F. Ambrose. Avonside, Clifton, Bristol.
1871. *King, Rev. Herbert Poole. The Rectory, Stourton, Bath.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1883. *King, John Godwin. Wainsford, Lymington, Hants.
1870. ‡King, John Thomson. 4 Clayton-square, Liverpool.
King, Joseph. Welford House, Greenhill, Hampstead, London, N.W.
1883. *King, Joseph, jun. 6 Wedderburn-road, Hampstead, London, N.W.
1860. *King, Mervyn Kersteman. 1 Vittoria-square, Clifton, Bristol.
1875. *King, Percy L. 5 Clifton Park, Bristol.
1870. ‡King, William. 5 Beach Lawn, Waterloo, Liverpool.
1889. §King, Sir William. Stratford Lodge, Southsea.
1869. ‡Kingdon, K. Taddiford, Exeter.
1876. §Kingston, Thomas. The Limes, Clewer, near Windsor.
1875. §KINGZETT, CHARLES T., F.C.S. Elmstead Knoll, Chislehurst, Kent.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1892. ‡Kinnear, The Hon. Lord, F.R.S.E. Blair Castle, Culross, N.B.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1860. ‡KIRKMAN, Rev. THOMAS P., M.A., F.R.S. Fernroyd, St. Margaret's-road, Bowdon, Cheshire.
1875. ‡*Kirsop, John. 6 Queen's-crescent, Glasgow.*
1883. ‡*Kirsop, Mrs. 6 Queen's-crescent, Glasgow.*
1870. ‡Kitchener, Frank E. Newcastle, Staffordshire.
1890. *KITSON, Sir JAMES, Bart., M.P. Gledhow Hall, Leeds.
1886. ‡Klein, Rev. L. Martial. University College, Dublin.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1886. ‡Knight, J. M. Bushwood, Wanstead, Essex.
1883. ‡*Knight, J. R. 32 Lincoln's Inn-fields, London, W.C.*
1888. ‡Knott, Professor Cargill G., D.Sc., F.R.S.E. 2 Lauriston Park, Edinburgh.
1872. *Knott, George, LL.B., F.R.A.S. Knowles Lodge, Cuckfield, Hayward's Heath, Sussex.
1887. *Knott, Herbert. Wharf Street Mills, Ashton-under-Lyne.
1887. *Knott, John F. Staveleigh, Stalybridge, Cheshire.
1887. ‡Knott, Mrs. Staveleigh, Stalybridge, Cheshire.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1874. ‡Knowles, William James. Flixton-place, Ballymena, Co. Antrim.
1883. ‡Knowlys, Rev. C. Hesketh. The Rectory, Roe-lane, Southport.
1883. ‡Knowlys, Mrs. C. Hesketh. The Rectory, Roe-lane, Southport.
1876. ‡Knox, David N., M.A., M.B. 24 Elmbank-crescent, Glasgow.
*Knox, George James. 27 Portland-terrace, Regent's Park, London, N.W.
1875. *Knubley, Rev. E. P., M.A. Staveley Rectory, Leeds.
1883. ‡Knubley, Mrs. Staveley Rectory, Leeds.
1892. §Kohn, Dr. Charles A. University College, Liverpool.
1890. *Krauss, John Samuel. Whitecot, Wilmslow, Cheshire.
1888. *Kunz, G. F. Care of Messrs. Tiffany & Co., Union-square, New York City, U.S.A.
1881. ‡Kurobe, Hiroo. Legation of Japan, 9 Cavendish-square, London, W.
1870. ‡Kynaston, Josiah W., F.C.S. Kensington, Liverpool.
1865. ‡*Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.*

1858. ‡Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1884. ‡Laflamme, Rev. Professor J. C. K. Laval University, Quebec, Canada.
1885. *Laing, J. Gerard. 1 Elm-court, Temple, London, E.C.

Year of Election.

1870. §Laird, John. Grosvenor-road, Claughton, Birkenhead.
1882. ‡*Lake, G. A. K., M.D. East Park-terrace, Southampton.*
1877. ‡Lake, W. C., M.D. Teignmouth.
1859. ‡Lalor, John Joseph, M.R.I.A. City Hall, Cork Hill, Dublin.
1889. *Lamb, Edmund, M.A. Union Club, Trafalgar-square, London, S.W.
1887. ‡Lamb, Horace, M.A., F.R.S., Professor of Pure Mathematics in the Owens College, Manchester. Burton-road, Didsbury, Manchester.
1887. ‡Lamb, James. Kenwood, Bowdon, Cheshire.
1883. ‡Lamb, W. J. 11 Gloucester-road, Birkdale, Southport.
1883. ‡LAMBERT, Rev. BROOKE, LL.B. The Vicarage, Greenwich, Kent, S.E.
1893. §Lambert, J. W., J.P. Lenton Firs, Nottingham.
1884. ‡Lamborn, Robert H. Montreal, Canada.
1893. §Lamplugh, G. W., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.
1890. ‡Lamport, Edward Parke. Greenfield Well, Lancaster.
1884. ‡Lancaster, Alfred. Fern Bank, Burnley, Lancashire.
1871. ‡Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1886. ‡Lancaster, W. J., F.G.S. Colmore-row, Birmingham.
1877. ‡Landon, Frederic George, M.A., F.R.A.S. 59 Tresillian-road, St. John's, London, S.E.
1883. ‡Lang, Rev. Gavin. Inverness.
1859. ‡Lang, Rev. John Marshall, D.D. Barony, Glasgow.
1886. *LANGLEY, J. N., M.A., F.R.S. Trinity College, Cambridge.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
1865. ‡LANKESTER, E. RAY, M.A., LL.D., F.R.S., Linacre Professor of Human and Comparative Anatomy in the University of Oxford. 2 Bradmore-road, Oxford.
1880. *LANSDELL, Rev. HENRY, D.D., F.R.A.S., F.R.G.S. Morden College, Blackheath, London, S.E.
1884. §Lanza, Professor G. Massachusetts Institute of Technology, Boston, U.S.A.
1878. ‡Lapper, E., M.D. 61 Harcourt-street, Dublin.
1885. ‡LAPWORTH, CHARLES, LL.D., F.R.S., F.G.S., Professor of Geology and Mineralogy in the Mason Science College, Birmingham. 13 Duchess-road, Edgbaston, Birmingham.
1887. ‡Larmor, Alexander. Clare College, Cambridge.
1881. ‡LARMOR, JOSEPH, M.A., D.Sc., F.R.S. St. John's College, Cambridge.
1883. §Lascelles, B. P. The Moat, Harrow.
1870. *LATHAM, BALDWIN, M.Inst.C.E., F.G.S. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.G.S. Catesby House, Manor-road, Barnet, Herts.
1891. ‡Laurie, A. P. 49 Beaumont-square, London, E.
1888. ‡Laurie, Colonel R. P., C.B. 79 Farringdon-street, London, E.C.
1892. §Laurie, Malcolm, B.A., B.Sc., F.L.S. King's College, Cambridge.
1883. ‡Laurie, Major-General. Oakfield, Nova Scotia.
1870. *Law, Channell. Ilsham Dene, Torquay.
1878. ‡Law, Henry, M.Inst.C.E. 9 Victoria-chambers, London, S.W.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
1884. §Law, Robert. Fenny Royd Hall, Hipperholme, Halifax, Yorkshire.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1881. ‡Lawrence, Rev. F., B.A. The Vicarage, Westow, York.
1889. §Laws, W. G., M.Inst.C.E. 5 Winchester-terrace, Newcastle-upon-Tyne.
1875. ‡Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1885. ‡Lawson, James. 8 Church-street, Huntly, N.B.

Year of
Election.

1868. *Lawson, M. Alexander, M.A., F.L.S. Ootâcamund, Bombay.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
1888. §Layard, Miss Nina F. 1 Park-place, Fonnereau-road, Ipswich.
1856. ‡Lea, Henry. 38 Bennett's-hill, Birmingham.
1883. *Leach, Charles Catterall. Seghill, Northumberland.
1883. §Leach, John. Claremont, Levenshulme, Manchester.
1875. ‡Leach, Colonel Sir G., K.C.B., R.E. 6 Wetherby-gardens, London, S.W.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. 6 Sussex-place, Regent's Park, London, N.W.
1884. *Leahy, John White, J.P. South Hill, Killarney, Ireland.
1884. ‡Learmont, Joseph B. 120 Mackay-street, Montreal, Canada.
1847. *Leatham, Edward Aldam. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
1863. ‡Leavers, J. W. The Park, Nottingham.
1884. *Leavitt, Erasmus Darwin. 2 Central-square, Cambridgeport, Massachusetts, U.S.A.
1872. ‡Lebour, G. A., M.A., F.G.S., Professor of Geology in the College of Physical Science, Newcastle-on-Tyne.
1884. ‡Leckie, R. G. Springhill, Cumberland County, Nova Scotia.
1883. ‡*Lee, Daniel W. Halton Bank, Pendleton, near Manchester.*
1861. ‡Lee, Henry. Sedgeley Park, Manchester.
1887. *Lee, Sir Joseph Cooksey. Park Gate, Altrincham.
1891. §Lee, Mark. 8 Llandaff-road, Cardiff.
1884. *Leech, Bosdin T. Oak Mount, Timperley, Cheshire.
1887. ‡Leech, D. J., M.D., Professor of Materia Medica in the Owens College, Manchester. Elm House, Whalley Range, Manchester.
1892. *Lees, Charles H., M.Sc. 6 Heald-road, Rusholme, Manchester.
1886. *Lees, Lawrence W. Claregate, Tettenhall, Wolverhampton.
1882. ‡Lees, R. W. Moira-place, Southampton.
1859. ‡Lees, William, M.A. 12 Morningside-place, Edinburgh.
1883. *Leese, Miss H. K. 3 Lord-street West, Southport.
*Leese, Joseph. 3 Lord-street West, Southport.
1889. *Leeson, John Rudd, M.D., C.M., F.L.S., F.G.S. Clifden House, Twickenham, Middlesex.
1881. ‡Le Feuvre, J. E. Southampton.
1872. ‡Lefevre, The Right Hon. G. Shaw, M.P., F.R.G.S. 18 Bryanston square, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1892. §Lehfeldt, Robert A. Firth College, Sheffield.
1868. ‡Leicester, The Right Hon. the Earl of, K.G. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1890. §Leigh, Marshall. 22 Goldsmid-road, Brighton.
1891. ‡Leigh, W. W. Treharris, R.S.O., Glamorganshire.
1886. ‡Leipner, Adolph, Professor of Botany in University College, Bristol. 38 Hampton Park, Bristol.
1867. ‡Leishman, James. Gateacre Hall, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1882. §Lemon, James, M.Inst.C.E., F.G.S. 11 The Avenue, Southampton.
1867. ‡Leng, Sir John, M.P. 'Advertiser' Office, Dundee.
1878. ‡Lennon, Rev. Francis. The College, Maynooth, Ireland.
1887. *Leon, John T. 38 Portland-place, London, W.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1884. ‡Lesage, Louis. City Hall, Montreal, Canada.
1871. ‡Leslie, Alexander, M.Inst.C.E. 72 George-street, Edinburgh.

Year of Election.

1890. *Lester, Joseph Henry. 51 Arcade-chambers, St. Mary's Gate Manchester.
1883. §Lester, Thomas. Fir Bank, Penrith.
1880. ‡LETCHER, R. J. Lansdowne-terrace, Walters-road, Swansea.
1887. ‡*Leverkus, Otto. The Downs, Prestwich, Manchester.*
1890. ‡Levy, J. H. Florence, 12 Abbeville-road South, Clapham Park, London, S.W.
1893. *Lewes, Vivian B., F.C.S., Professor of Chemistry in the Royal Naval College, Greenwich.
1879. ‡Lewin, Colonel, F.R.G.S. Garden Corner House, Chelsea Embankment, London, S.W.
1870. ‡LEWIS, ALFRED LIONEL. 54 Highbury-hill, London, N.
1891. ‡Lewis, D., J.P. 44 Park-place, Cardiff.
1891. §Lewis, D. Morgan, M.A. University College, Aberystwith.
1891. ‡Lewis, W. Lyncombe Villa, Cowbridge-road, Cardiff.
1891. ‡Lewis, W. 22 Duke-street, Cardiff.
1891. ‡Lewis, W. Henry. Bryn Rhos, Llanishen, Cardiff.
1884. *Lewis, Sir W. T. The Mardy, Aberdare.
1860. ‡LIDDELL, The Very Rev. H. G., D.D. Ascot, Berkshire.
1887. ‡Liebermann, L. 54 Portland-street, Manchester.
1876. ‡Lietke, J. O. 30 Gordon-street, Glasgow.
1887. *Lightbown, Henry. Weaste Hall, Pendleton, Manchester.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, The Right Rev. CHARLES GRAVES, Lord Bishop of, D.D., F.R.S., M.R.I.A. The Palace, Henry-street, Limerick.
1887. ‡Limpach, Dr. Crumpsall Vale Chemical Works, Manchester.
1878. ‡Lincolne, William. Ely, Cambridgeshire.
1881. *Lindley, William, M.Inst.C.E., F.G.S. 74 Shooters Hill-road, Blackheath, London, S.E.
1871. ‡Lindsay, Rev. T. M., M.A., D.D. Free Church College, Glasgow.
1883. ‡*Lipscomb, Mrs. Lancelot C. d'A. 95 Elgin-crescent, London, W.*
1883. ‡Lisle, H. Claud. Nantwich.
1882. *Lister, Rev. Henry, M.A. Hawridge Rectory, Berkhampstead.
1888. ‡Lister, J. J. Leytonstone, Essex, E.
1861. *LIVEING, G. D., M.A., F.R.S., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1876. *Liversidge, Archibald, F.R.S., F.C.S., F.G.S., F.R.G.S., Professor of Chemistry and Mineralogy in the University of Sydney, N.S.W.
1864. §Livesay, J. G. Cromartie House, Ventnor, Isle of Wight.
1880. ‡LLEWELYN, Sir JOHN T. D., Bart. Penllegare, Swansea.
Lloyd, Rev. A. R. Hengold, near Oswestry.
1889. ‡Lloyd, Rev. Canon. The Vicarage, Rye Hill, Newcastle-upon-Tyne.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B., J.P. Edgbaston-grove, Birmingham.
1865. ‡Lloyd, John. Queen's College, Birmingham.
1886. ‡Lloyd, John Henry. Ferndale, Carpenter-road, Edgbaston, Birmingham.
1891. *Lloyd, R. J., M.A., D.Litt. 46 Chatham-street, Liverpool.
1886. ‡Lloyd, Samuel. Farm, Sparkbrook, Birmingham.
1865. *Lloyd, Wilson, F.R.G.S. Myvod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. City of London College, Moorgate-street, London, E.C.
1892. §Loch, C. S., B.A. 15A Buckingham-street, London, W.C.
1867. **Locke, John. Whitehall Club, London, S.W.*
1892. ‡Lockhart, Robert Arthur. 10 Polwarth-terrace, Edinburgh.

Year of Election.

1863. ‡LOCKYER, J. NORMAN, C.B., F.R.S., F.R.A.S. Royal College of Science, South Kensington, London, S.W.
1886. *LODGE, ALFRED, M.A., Professor of Pure Mathematics in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1875. *LODGE, OLIVER J., D.Sc., LL.D., F.R.S., Professor of Physics in University College, Liverpool. 2 Grove-park, Liverpool.
1889. ‡Logan, William. Langley Park, Durham.
1876. ‡Long, H. A. Charlotte-street, Glasgow.
1871. *Long, John Jex. 11 Doune-terrace, Kelvinside, Glasgow.
1883. *Long, William. Thelwall Heys, near Warrington.
1883. ‡Long, Mrs. Thelwall Heys, near Warrington.
1883. ‡Long, Miss. Thelwall Heys, near Warrington.
1866. ‡Longdon, Frederick. Osmaston-road, Derby.
1883. ‡Longe, Francis D. Coddenham Lodge, Cheltenham.
1883. ‡Longmaid, William Henry. 4 Rawlinson-road, Southport.
1875. *Longstaff, George Blundell, M.A., M.D., F.C.S., F.S.S. Highlands, Putney Heath, S.W.
1872. *Longstaff, Llewellyn Wood, F.R.G.S. Ridgelands, Wimbledon, Surrey.
1881. *Longstaff, Mrs. Ll. W. Ridgelands, Wimbledon, Surrey.
1883. *Longton, E. J., M.D. Lord-street, Southport.
1861. *Lord, Edward. Adamroyd, Todmorden.
1889. ‡Lord, Riley. Highfield House, Gosforth, Newcastle-upon-Tyne.
1883. *Louis, D. A., F.C.S. 77 Shirland-gardens, London, W.
1887. *Love, A. E. H. St. John's College, Cambridge.
1886. *Love, E. F. J., M.A. The University, Melbourne, Australia.
1876. *Love, James, F.R.A.S., F.G.S., F.Z.S. 11 Notting Hill-square, London, W.
1883. ‡Love, James Allen. 8 Eastbourne-road West, Southport.
1875. *Lovett, W. Jesse, F.I.C. 75 Clarendon-road, Crumpsall, Manchester.
1892. §Lovibond, J. W. Salisbury, Wiltshire.
1889. ‡Low, Charles W. 84 Westbourne-terrace, London, W.
1867. *Low, James F. Monifieth, by Dundee.
1885. §Lowdell, Sydney Poole. Baldwyn's Hill, East Grinstead, Sussex.
1891. §Lowdon, John. Hillside, Barry, Cardiff.
1885. *Lowe, Arthur C. W. Gosfield Hall, Halstead, Essex.
1892. ‡Lowe, D. T. Heriot's Hospital, Edinburgh.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.R.M.S. Shirenewton Hall, near Chepstow.
1884. ‡*Lowe, F. J. Elm-court, Temple, London, E.C.*
1886. *Lowe, John Landor, M.Inst.C.E. Engineer's Office, Midland Railway, Derby.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1881. ‡Lubbock, Arthur Rolfe. High Elms, Hayes, Kent.
1853. *LUBBOCK, The Right Hon. Sir JOHN, Bart., M.P., D.C.L., LL.D., F.R.S., F.L.S., F.G.S. High Elms, Down, Kent.
1881. ‡Lubbock, John B. High Elms, Hayes, Kent.
1870. ‡Lubbock, Montague, M.D. 19 Grosvenor-street, London, W.
1889. ‡Lucas, John. 1 Carlton-terrace, Low Fell, Gateshead.
1878. ‡Lucas, Joseph. Tooting Graveney, London, S.W.
1889. ‡Luckley, George. 7 Victoria-square, Newcastle-upon-Tyne.
1891. *Lucovich, Count A. The Rise, Llandaff.
1875. ‡Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1881. ‡Luden, C. M. 4 Bootham-terrace, York.
1873. ‡*Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.*

Year of Election.

1866. *Lund, Charles. Ilkley, Yorkshire.
1873. ‡Lund, Joseph. Ilkley, Yorkshire.
1850. *Lundie, Cornelius. 32 Newport-road, Cardiff.
1892. ‡Lunn, Robert. Geological Survey Office, Sheriff Court House, Edinburgh.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1883. *Lupton, Arnold, M.Inst.C.E., F.G.S., Professor of Mining Engineering in Yorkshire College. 6 De Grey-road, Leeds.
1874. *LUPTON, SYDNEY, M.A. Grove Cottage, Roundhay, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1871. ‡Lyell, Sir Leonard, Bart., M.P., F.G.S. 48 Eaton-place, London, S.W.
1884. ‡Lyman, A. Clarence. 84 Victoria-street, Montreal, Canada.
1884. ‡Lyman, H. H. 74 McTavish-street, Montreal, Canada.
1874. ‡Lynam, James. Ballinasloe, Ireland.
1885. §Lyon, Alexander, jun. 52 Carden-place, Aberdeen.
1862. *LYTE, F. MAXWELL, F.C.S. 60 Finborough-road, London, S.W.

1852. ‡McAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1876. *MACADAM, WILLIAM IVISON., F.R.S.E., F.I.C., F.C.S. Surgeons' Hall, Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Torrisdale, Cambridge.
1878. ‡MACALISTER, DONALD, M.A., M.D., B.Sc. St. John's College, Cambridge.
1879. §MacAndrew, James J., F.L.S Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, Mrs. J. J. Lukesland, Ivybridge, South Devon.
1883. §MacAndrew, William. Westwood House, near Colchester.
1866. *M'Arthur, Alexander, F.R.G.S. 79 Holland Park, London, W.
1884. ‡Macarthur, D. Winnipeg, Canada.
1834. MACAULAY, JAMES, A.M., M.D. 25 Carlton-vale, London, N.W.
1840. **MacBrayne, Robert. 65 West Regent-street, Glasgow.*
1884. ‡McCabe, T., Chief Examiner of Patents. Patent Office, Ottawa, Canada.
1886. ‡MacCarthy, Rev. E. F. M., M.A. 93 Hagley-road, Birmingham.
1887. *McCarthy, James. Bangkok, Siam.
1884. *McCarthy, J. J., M.D. 83 Wellington-road, Dublin.
1884. ‡McCausland, Orr. Belfast.
1891. *McClean, Frank, M.A., F.S.S. Rusthall House, Tunbridge Wells.
1876. *M'CLELLAND, A. S. 4 Crown-gardens, Dowanhill, Glasgow.
1868. ‡M'CLINTOCK, Admiral Sir FRANCIS L., R.N., K.C.B., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1878. *M'Comas, Henry. Homestead, Dundrum, Co. Dublin.
1892. *McCowan, John, M.A., D.Sc. University College, Dundee.
1892. ‡McCrae, George. 3 Dick-place, Edinburgh.
1883. ‡McCrossan, James. 92 Huskisson-street, Liverpool.
1886. ‡McDonald, John Allen. Hillsboro' House, Derby.
1884. ‡MacDonald, Kenneth. Town Hall, Inverness.
1884. *McDonald, W. C. 891 Sherbrooke-street, Montreal, Canada.
1878. ‡*McDonnell, Alexander. St. John's, Island Bridge, Dublin.*
1884. ‡MacDonnell, Mrs. F. H. 1433 St. Catherine-street, Montreal, Canada.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
1883. ‡MacDonnell, Rev. Canon J. C., D.D. Misterton Rectory, Lutterworth.

Year of Election.

1878. ‡McDonnell, James. 32 Upper Fitzwilliam-street, Dublin.
1884. ‡Macdougall, Alan, M.Inst.C.E. 32 Adelaide-street East, Toronto, Canada.
1884. ‡McDougall, John. 35 St. François Xavier-street, Montreal, Canada.
1881. ‡Macfarlane, Alexander, D.Sc., F.R.S.E., Professor of Physics in the University of Texas. Austin, Texas, U.S.A.
1871. ‡M'Farlane, Donald. The College Laboratory, Glasgow.
1885. ‡Macfarlane, J. M., D.Sc., F.R.S.E. 15 Scotland-street, Edinburgh.
1879. ‡Macfarlane, Walter, jun. 12 Lynedoch-crescent, Glasgow.
1884. ‡Macfie, K. N., B.A., B.C.L. Winnipeg, Canada.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1888. ‡MacGeorge, James. 67 Marloes-road, Kensington, London, W.
1884. ‡MacGillivray, James. 42 Cathcart-street, Montreal, Canada.
1884. ‡MacGoun, Archibald, jun., B.A., B.C.L. 19 Place d'Armes, Montreal, Canada.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1885. ‡Macgregor, Alexander, M.D. 256 Union-street, Aberdeen.
1884. *MacGregor, James Gordon, M.A., D.Sc., F.R.S.E., Professor of Physics in Dalhousie College, Halifax, Nova Scotia, Canada.
1886. ‡*McGregor, William. Kohima Lodge, Bedford.*
1885. ‡M'Gregor-Robertson, J., M.A., M.B. 400 Great Western-road, Glasgow.
1876. ‡M'Grigor, Alexander B., LL.D. 19 Woodside-terrace, Glasgow.
1867. *M'Intosh, W. C., M.D., LL.D., F.R.S., F.R.S.E., F.L.S., Professor of Natural History in the University of St. Andrews. 2 Abbotsford-crescent, St. Andrews, N.B.
1884. ‡McIntyre, John, M.D. Odiham, Hants.
1883. ‡Mack, Isaac A. Trinity-road, Bootle.
1884. ‡Mackay, Alexander Howard, B.A., B.Sc. The Academy, Pictou, Nova Scotia, Canada.
1885. §Mackay, John Yule, M.D. The University, Glasgow.
1873. ‡McKendrick, John G., M.D., LL.D., F.R.S., F.R.S.E., Professor of Physiology in the University of Glasgow. The University, Glasgow.
1883. ‡McKendrick, Mrs. The University, Glasgow.
1880. *Mackenzie, Colin. Junior Athenæum Club, Piccadilly, London, W.
1884. ‡McKenzie, Stephen, M.D. 26 Finsbury-circus, London, E.C.
1884. ‡McKenzie, Thomas, B.A. School of Science, Toronto, Canada.
1883. ‡Mackeson, Henry. Hythe, Kent.
1865. ‡Mackeson, Henry B., F.G.S. Hythe, Kent.
1872. *Mackey, J. A. 1 Westbourne-terrace, Hyde Park, London, W.
1867. ‡Mackie, Samuel Joseph. 17 Howley-place, London, W.
1884. ‡McKilligan, John B. 387 Main-street, Winnipeg, Canada.
1887. ‡Mackinder, H. J., M.A., F.R.G.S. Christ Church, Oxford.
1867. *Mackinlay, David. 6 Great Western-terrace, Hillhead, Glasgow.
1889. ‡McKinley, Rev. D. 33 Milton-street, West Hartlepool.
1891. ‡Mackintosh, A. C. Temple Chambers, Cardiff.
1850. ‡Macknight, Alexander. 20 Albany-street, Edinburgh.
1867. ‡*Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.*
1872. *McLachlan, Robert, F.R.S., F.L.S. West View, Clarendon-road, Lewisham, S.E.
1892. §Maclagan, Sir Douglas, M.D., LL.D., F.R.S.E., Professor of Medical Jurisprudence in the University of Edinburgh. 28 Heriot-row, Edinburgh.
1892. ‡Maclagan, Philip K. D. 14 Belgrave-place, Edinburgh.
1892. ‡Maclagan, R. Craig, M.D., F.R.S.E. 5 Coates-crescent, Edinburgh.

Year of Election.

1873. ‡McLandsborough, John, M.Inst.C.E., F.R.A.S., F.G.S. Manningham, Bradford, Yorkshire.
1885. *M'Laren, The Hon. Lord, F.R.S.E., F.R.A.S. 46 Moray-place, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1882. ‡Maclean, Inspector-General, C.B. 1 Rockstone-terrace, Southampton.
1892. *Maclean, Magnus, M.A., F.R.S.E. The University, Glasgow.
1884. ‡McLennan, Frank. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, Hugh. 317 Drummond-street, Montreal, Canada.
1884. ‡McLennan, John. Lancaster, Ontario, Canada.
1868. §McLeod, Herbert, F.R.S., F.C.S., Professor of Chemistry in the Royal Indian Civil Engineering College, Cooper's Hill, Staines.
1892. ‡*Macleod, Reginald. Woodhall, Midlothian.*
1892. ‡Macleod, W. Bowman. 16 George-square, Edinburgh.
1861. *Maclure, John William, M.P., F.R.G.S., F.S.S. Whalley Range, Manchester.
1883. *McMahon, Lieut.-General C. A. 20 Nevern-square, South Kensington, London, S.W.
1883. ‡MacMahon, Major P. A., R.A., F.R.S., Professor of Electricity in the Artillery College, Woolwich. 40 Shaftesbury-avenue, London, W.C.
1878. *M'Master, George, M.A., J.P. Donnybrook, Ireland.
1862. ‡Macmillan, Alexander. 21 Portland-place, London, W.
1888. ‡McMillan, Robert. 20 Aubrey-street, Liverpool.
1874. ‡MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1884. ‡McMurrick, J. Playfair. Cincinnati, Ohio, U.S.A.
1867. ‡M'Neill, John. Balhousie House, Perth.
1883. ‡McNicoll, Dr. E. D. 15 Manchester-road, Southport.
1878. ‡Macnie, George. 59 Bolton-street, Dublin.
1887. ‡Maconochie, Archibald White. Care of Messrs. Maconochie Bros., Lowestoft.
1883. ‡Macpherson, J. 44 Frederick-street, Edinburgh.
1886. ‡Macpherson, Lieut.-Colonel J. C., R.E. Ordnance Survey Office, Southampton.
1887. §McRae, Charles, M.A., F.L.S. Department of Science and Art, South Kensington, London, S.W.
*Macrory, Edmund, M.A. 2 Ilchester-gardens, Prince's-square, London, W.
1883. ‡*McWhirter, William.* 170 *Kent-road, Glasgow.*
1887. ‡Macy, Jesse. Grinnell, Iowa, U.S.A.
1883. ‡Madden, W. H. Marlborough College, Wilts.
1883. ‡Maggs, Thomas Charles, F.G.S. 56 Clarendon-villas, West Brighton.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. *Magnus, Sir Philip, B.Sc. 48 Gloucester-place, Portman-square, London, W.
1878. ‡Mahony, W. A. 34 College-green, Dublin.
1869. ‡Main, Robert. The Admiralty, Whitehall, London, S.W.
1887. ‡Mainprice, W. S. Longcroft, Altrincham, Cheshire.
1885. *Maitland, Sir James R. G., Bart. Stirling, N.B.
1883. ‡Maitland, P. C. 136 Great Portland-street, London, W.
*Malcolm, Frederick. Morden College, Blackheath, London, S.E.
1881. ‡Malcolm, Lieut.-Colonel, R.E. 72 Nunthorpe-road, York.
1874. ‡Malcolmson, A. B. Friends' Institute, Belfast.
1889. ‡Maling, C. T. 14 Ellison-place, Newcastle-upon-Tyne.
1857. ‡Mallet, John William, Ph.D., M.D., F.R.S., F.C.S., Professor of Chemistry in the University of Virginia, Albemarle Co., U.S.A.

Year of Election.

1887. ‡MANCHESTER, The Right Rev. the Lord Bishop of, D.D. Bishop's Court, Manchester.
1870. ‡Manifold, W. H., M.D. 45 Rodney-street, Liverpool.
1885. ‡Mann, George. 72 Bon Accord-street, Aberdeen.
1888. ‡Mann, W. J. Rodney House, Trowbridge.
1878. §Manning, Robert. 4 Upper Ely-place, Dublin.
1864. ‡Mansel-Pleydell, J. C. Whatcombe, Blandford.
1888. ‡Mansergh, James, M.Inst.C.E. 3 Westminster-chambers, London, S.W.
1891. ‡Manuel, James. 175 Newport-road, Cardiff.
1889. ‡Manville, E. 3 Prince's-mansions, Victoria-street, London, S.W.
1887. *March, Henry Colley, M.D. 2 West-street, Rochdale.
1870. ‡Marcoartu, His Excellency Don Arturo de. Madrid.
1887. ‡Margetson, J. Charles. The Rocks, Limpley, Stoke.
1883. ‡Marginson, James Fleetwood. The Mount, Fleetwood, Lancashire.
1887. §Markham, Christopher A., F.R.Met.Soc. Spratton, Northampton.
1864. ‡MARKHAM, CLEMENTS R., C.B., F.R.S., F.L.S., Pres.R.G.S., F.S.A. 21 Eccleston-square, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
1888. ‡Marling, W. J. Stanley Park, Stroud, Gloucestershire.
1888. ‡Marling, Lady. Stanley Park, Stroud, Gloucestershire.
1881. *MARR, JOHN EDWARD, M.A., F.R.S., F.G.S. St. John's College, Cambridge.
1887. ‡Marsden, Benjamin. Westleigh, Heaton Mersey, Manchester.
1887. ‡*Marsden, Joseph. Ardenlea, Heaton, near Bolton.*
1884. *Marsden, Samuel. St. Louis, Missouri, U.S.A.
1892. *Marsden-Smedley, J. B. Lea Green, Cromford, Derbyshire.
1883. *Marsh, Henry. Cressy House, Woodsley-road, Leeds.
1887. ‡Marsh, J. E., B.A. The Museum, Oxford.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1889. *MARSHALL, ALFRED, M.A., LL.D., Professor of Political Economy in the University of Cambridge. Balliol Croft, Madingley-road, Cambridge.
1889. ‡Marshall, Frank, B.A. 31 Grosvenor-place, Newcastle-upon-Tyne.
1892. §Marshall, Hugh, D.Sc., F.R.S.E. Druim Shellach, Liberton, Midlothian.
1881. *Marshall, John, F.R.A.S., F.G.S. Church Institute, Leeds.
1890. ‡Marshall, John. Derwent Island, Keswick.
1881. ‡Marshall, John Ingham Fearby. 28 St. Saviourgate, York.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1876. ‡*Marshall, Peter. 6 Parkgrove-terrace, Glasgow.*
1886. *MARSHALL, WILLIAM BAYLEY, M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1849. *MARSHALL, WILLIAM P., M.Inst.C.E. Richmond Hill, Edgbaston, Birmingham.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1883. ‡Marten, Henry John. 4 Storey's-gate, London, S.W.
1887. *Martin, Rev. H. A. Laxton Vicarage, Newark.
1891. *Martin, Edward P., J.P. Dowlais, Glamorgan.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1878. ‡MARTIN, H. NEWELL, M.A., M.D., D.Sc., F.R.S., Professor of Biology in Johns Hopkins University, Baltimore, U.S.A.
1883. *MARTIN, JOHN BIDDULPH, M.A., F.S.S. 17 Hyde Park-gate, London, S.W.
1884. §Martin, N. H., F.L.S. 8 Windsor-crescent, Newcastle-upon-Tyne.
1889. *Martin, Thomas Henry, Assoc.M.Inst.C.E. Lyon House, New Barnet, Herts.

Year of Election.

1890. §Martindale, William. 19 Devonshire-street, Portland-place, London, W.
*Martineau, Rev. James, LL.D., D.D. 35 Gordon-square, London, W.C.
1865. ‡Martineau, R. F. 18 Highfield-road, Edgbaston, Birmingham.
1883. ‡Marwick, Sir James, LL.D. Killermont, Maryhill, Glasgow.
1891. ‡Marychurch, J. G. 46 Park-street, Cardiff.
1878. ‡Masaki, Taiso. Japanese Consulate, 84 Bishopsgate-street Within, London, E.C.
1847. ‡Maskelyne, Nevil Story, M.A., F.R.S., F.G.S., Professor of Mineralogy in the University of Oxford. Basset Down House, Swindon.
1886. ‡Mason, Hon. J. E. Fiji.
1879. ‡Mason, James, M.D. Montgomery House, Sheffield.
1893. *Mason, Thomas. 6 Pelham-road, Sherwood Rise, Nottingham.
1891. §Massey, William H., M.Inst.C.E. Twyford, R.S.O., Berkshire.
1885. ‡Masson, Orme, D.Sc. 58 Great King-street, Edinburgh.
1883. ‡Mather, Robert V. Birkdale Lodge, Birkdale, Southport.
1887. *Mather, William, M.P., M.Inst.C.E. Salford Iron Works, Manchester.
1890. ‡Mathers, J. S. 1 Hanover-square, Leeds.
1865. ‡Mathews, C. E. Waterloo-street, Birmingham.
1865. *Mathews, G. S. 32 Augustus-road, Edgbaston, Birmingham.
1889. ‡Mathews, John Hitchcock. 1 Queen's-gardens, Hyde Park, London, W.
1861. *Mathews, William, M.A., F.G.S. 60 Harborne-road, Birmingham.
1881. ‡Mathwin, Henry, B.A. Bickerton House, Southport.
1883. ‡Mathwin, Mrs. 40 York-road, Birkdale, Southport.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1885. ‡Matthews, James. Springhill, Aberdeen.
1885. ‡Matthews, J. Duncan. Springhill, Aberdeen.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-upon-Tyne.
1890. ‡*Maund, E. A. 294 Regent-street, London, W.*
1893. §Mavor, Professor James. University of Toronto, Canada.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Kenley, Surrey.
1876. ‡Maxton, John. 6 Belgrave-terrace, Glasgow.
1887. ‡Maxwell, James. 29 Princess-street, Manchester.
*Maxwell, Robert Perceval. Finnebrogue, Downpatrick.
1883. §May, William, F.G.S., F.R.G.S. Northfield, St. Mary Cray, Kent.
1883. ‡Mayall, George. Clairville, Birkdale, Southport.
1884. *Maybury, A. C., D.Sc. 19 Bloomsbury-square, London, W.C.
1878. *Mayne, Thomas. 33 Castle-street, Dublin.
1878. ‡Meath, The Right Rev. C. P. Reichel, D.D., Bishop of. Dundrum Castle, Dublin.
1884. ‡*Mecham, Arthur.* 11 *Newton-terrace, Glasgow.*
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1879. §Meiklejohn, John W. S., M.D. 105 Holland-road, London, W.
1887. ‡Meischke-Smith, W. Rivala Lumpore, Salengore, Straits Settlements.
1881. *Meldola, Raphael, F.R.S., F.R.A.S., F.C.S., F.I.C., Professor of Chemistry in the Finsbury Technical College, City and Guilds of London Institute. 6 Brunswick-square, London, W.C.
1867. ‡Meldrum, Charles, C.M.G., LL.D., F.R.S., F.R.A.S. Port Louis, Mauritius.
1883. ‡Mellis, Rev. James. 23 Park-street, Southport.
1879. *Mellish, Henry. Hodsock Priory, Worksop.

Year of Election.

1866. ‡MELLO, Rev. J. M., M.A., F.G.S. Mapperley Vicarage, Derby.
1883. §Mello, Mrs. J. M. Mapperley Vicarage, Derby.
1881. §Melrose, James. Clifton Croft, York.
1887. ‡Melvill, J. Cosmo, M.A. Kersal Cottage, Prestwich, Manchester.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1877. *Menabrea, General, Marquis of Valdora, LL.D. Chambéry, Savoie.
1862. ‡MENNELL, HENRY T. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1879. §MERIVALE, JOHN HERMAN, M.A., Professor of Mining in the College of Science, Newcastle-upon-Tyne.
1880. ‡Merry, Alfred S. Bryn Heulog, Sketty, near Swansea.
1889. *Merz, John Theodore. The Quarries, Newcastle-upon-Tyne.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. ‡MIALL, LOUIS C., F.R.S., F.L.S., F.G.S., Professor of Biology in the Yorkshire College, Leeds.
1886. ‡Middlemore, Thomas. Holloway Head, Birmingham.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1881. *Middlesbrough, The Right Rev. Richard Lacy, D.D., Bishop of Middlesbrough.
1893. §Middleton, A. 25 Lister-gate, Nottingham.
1883. ‡*Middleton, Henry. St. John's College, Cambridge.*
1881. ‡Middleton, R. Morton, F.L.S., F.Z.S. 15 Grange-road, West Hartlepool.
1889. ‡Milburn, John D. Queen-street, Newcastle-upon-Tyne.
1886. ‡Miles, Charles Albert. Buenos Ayres.
1881. §MILES, MORRIS. Warbourne, Hill-lane, Southampton.
1885. §MILL, HUGH ROBERT, D.Sc., F.R.S.E., Librarian R.G.S. 109 West End-lane, Hampstead, London, N.W.
1859. ‡Millar, John, J.P. Lisburn, Ireland.
1889. *Millar, Robert Cockburn. 30 York-place, Edinburgh.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1892. *Millard, William Joseph Kelson, M.D., F.R.G.S. Holmleigh, Rockleaze, Stoke Bishop, Bristol.
1882. ‡Miller, A. J. 15 East Park-terrace, Southampton.
1875. ‡Miller, George. Brentry, near Bristol.
1884. ‡*Miller, Mrs. Hugh. Lauriston-place, Edinburgh.*
1892. ‡Miller, Hugh, F.R.S.E., F.G.S. 3 Douglas-crescent, Edinburgh.
1888. ‡Miller, J. Bruce. Rubislaw Den North, Aberdeen.
1885. ‡Miller, John. 9 Rubislaw-terrace, Aberdeen.
1886. ‡Miller, Rev. John. The College, Weymouth.
1861. *Miller, Robert. Totteridge House, Hertfordshire, N.
1876. *Miller, Robert. 1 Lily Bank-terrace, Hillhead, Glasgow.
1884. ‡Miller, T. F., B.Ap.Sc. Napanee, Ontario, Canada.
1876. ‡Miller, Thomas Paterson. Cairns, Cambuslang, N.B.
1868. *MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in the Glasgow and West of Scotland Technical College, Glasgow. 60 John-street, Glasgow.
1880. §Mills, Mansfeldt H., M.Inst.C.E. Mansfield Woodhouse, Mansfield.
1834. Milne, Admiral Sir Alexander, Bart., G.C.B., F.R.S.E. Inveresk.
1885. ‡Milne, Alexander D. 40 Albyn-place, Aberdeen.
1882. *MILNE, JOHN, F.R.S., F.G.S., Professor of Mining and Geology in the Imperial College of Engineering, Tokio, Japan. Ingleside, Birdhurst Rise, South Croydon, Surrey.
1885. ‡Milne, J. D. 14 Rubislaw-terrace, Aberdeen.
1885. ‡Milne, William. 40 Albyn-place, Aberdeen.
1887. ‡Milne-Redhead, R., F.L.S. Holden Clough, Clitheroe.

Year of
Election.

1882. ‡Milnes, Alfred, M.A., F.S.S. 22A Goldhurst-terrace, South Hampstead, London, N.W.
1888. ‡*Milsom, Charles. 69 Pulteney-street, Bath.*
1880. ‡Minchin, G. M., M.A. Royal Indian Engineering College, Cooper's Hill, Surrey.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1876. ‡Mitchell, Andrew. 20 Woodside-place, Glasgow.
1883. ‡Mitchell, Charles T., M.A. 41 Addison-gardens North, Kensington, London, W.
1883. ‡Mitchell, Mrs. Charles T. 41 Addison-gardens North, Kensington, London, W.
1863. ‡Mitchell, C. Walker, LL.D. Newcastle-upon-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1885. ‡Mitchell, Rev. J. Mitford, B.A. 6 Queen's-terrace, Aberdeen.
1885. ‡Mitchell, P. Chalmers. Christ Church, Oxford.
1879. ‡MIVART, ST. GEORGE, Ph.D., M.D., F.R.S., F.L.S., F.Z.S. Hurstcote, Chilworth, Surrey.
1885. ‡Moffat, William. 7 Queen's-gardens, Aberdeen.
1864. ‡Mogg, John Rees. The Priory, Glastonbury.
1885. ‡Moir, James. 25 Carden-place, Aberdeen.
1883. ‡Mollison, W. L., M.A. Clare College, Cambridge.
1878. ‡Molloy, Constantine, Q.C. 65 Lower Leeson-street, Dublin.
1877. *Molloy, Rev. Gerald, D.D. 86 Stephen's-green, Dublin.
1884. ‡Monaghan, Patrick. Halifax (Box 317), Nova Scotia, Canada.
1887. *Mond, Ludwig, F.R.S., F.C.S. 20 Avenue-road, Regent's Park, London, N.W.
1891. *Mond, Robert Ludwig, B.A., F.R.S.E. 20 Avenue-road, Regent's Park, London, N.W.
1882. *Montagu, Samuel, M.P. 12 Kensington Palace-gardens, London, W.
1891. ‡Montefiore, Arthur, F.G.S., F.R.G.S. Care of London and South-Western Bank, South Hampstead, London, N.W.
1892. ‡Montgomery, Very Rev. J. F., D.D. 17 Athole-crescent, Edinburgh.
1872. ‡Montgomery, R. Mortimer. 3 Porchester-place, Edgware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1884. ‡Moore, George Frederick. 49 Hardman-street, Liverpool.
1881. §Moore, Henry. Collingham, Maresfield-gardens, Fitzjohn's-avenue, London, N.W.
1891. ‡Moore, John. Lindenwood, Park-place, Cardiff.
1890. ‡Moore, Major, R.E. School of Military Engineering, Chatham.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1857. *Moore, Rev. William Prior. Carrickmore, Galway, Ireland.
1871. ‡MORE, ALEXANDER G., F.L.S., M.R.I.A. 74 Leinster-road, Dublin.
1891. ‡Morel, P. Lavernock House, near Cardiff.
1881. ‡MORGAN, ALFRED. 50 West Bay-street, Jacksonville, Florida, U.S.A.
1873. ‡Morgan, Edward Delmar, F.R.G.S. 15 Roland-gardens, London, S.W.
1891. §Morgan, F. Forest Lodge, Ruspidge, Gloucestershire.
1885. ‡Morgan, John. 57 Thomson-street, Aberdeen.
1887. ‡Morgan, John Gray. 38 Lloyd-street, Manchester.
1891. ‡Morgan, Sir Morgan. Cardiff.
1882. §Morgan, Thomas. Cross House, Southampton.

Year of Election.

1878. ‡MORGAN, WILLIAM, Ph.D., F.C.S. Swansea.
1889. §Morison, J. Rutherford, M.D. 14 Saville-row, Newcastle-upon-Tyne.
1892. ‡Morison, John, M.D., F.G.S. Victoria-street, St. Albans.
1867. ‡Morison, William R. Dundee.
1893. §Morland, John, J.P. Glastonbury.
1891. ‡Morley, H. The Gas Works, Cardiff.
1883. *Morley, Henry Forster, M.A., D.Sc., F.C.S. 29 Kylemore-road, West Hampstead, London, N.W.
1889. ‡MORLEY, The Right Hon. JOHN, M.A., LL.D., F.R.S., M.P. 95 Elm Park-gardens, London, S.W.
1881. ‡Morrell, W. W. York City and County Bank, York.
1880. ‡Morris, Alfred Arthur Vennor. Wernolau, Cross Inn R.S.O., Carmarthenshire.
1883. ‡Morris, C. S. Millbrook Iron Works, Landore, South Wales.
1892. ‡Morris, Daniel, C.B., M.A., F.L.S. 11 Kew Gardens-road, Kew.
1883. ‡Morris, George Lockwood. Millbrook Iron Works, Swansea.
1880. §Morris, James. 6 Windsor-street, Uplands, Swansea.
1883. ‡Morris, John. 40 Wellesley-road, Liverpool.
1888. ‡Morris, J. W., F.L.S. The Woodlands, Bathwick Hill, Bath.
1880. ‡*Morris, M. I. E. The Lodge, Penclawdd, near Swansea.*
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1876. ‡Morris, Rev. S. S. O., M.A., R.N., F.C.S. H.M.S. 'Garnet,' S. Coast of America.
1874. ‡Morrison, G. J., M.Inst.C.E. Shanghai, China.
1890. ‡Morrison, Sir George W. Municipal Buildings, Leeds.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1886. ‡Morrison, John T. Scottish Marine Station, Granton, N.B.
1865. ‡Mortimer, J. R. St. John's-villas, Driffield.
1869. †Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 209 Edge-lane, Liverpool.
1858. *MORTON, HENRY JOSEPH. 2 Westbourne-villas, Scarborough.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1887. ‡Morton, Percy, M.A. Illtyd House, Brecon, South Wales.
1886. *Morton, P. F. Hook House, Hook, near Winchfield, Hampshire.
1883. ‡Moseley, Mrs. Firwood, Clevedon, Somerset.
1891. ‡*Moss Arthur J., M.B. Penarth, Glamorganshire.*
1878. *Moss, JOHN FRANCIS, F.R.G.S. Beechwood, Brincliffe, Sheffield.
1876. §Moss, RICHARD JACKSON, F.C.S., M.R.I.A. St. Aubyn's, Ballybrack, Co. Dublin.
1864. *Mosse, J. R. Conservative Club, London, S.W.
1892. ‡Mossman, R. C., F.R.S.E. 10 Blacket-place, Edinburgh.
1873. ‡Mossman, William. Ovenden, Halifax.
1892. *Mostyn, S. G., B.A. Colet House, Talgarth-road, London, W.
1869. §MOTT, ALBERT J., F.G.S. Detmore, Charlton Kings, Cheltenham.
1866. §MOTT, FREDERICK T., F.R.G.S. 2 College-street, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden Hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.
1878. *Moulton, J. Fletcher, M.A., Q.C., F.R.S. 57 Onslow-square, London, S.W.
1863. ‡Mounsey, Edward. Sunderland.
1861. *Mountcastle, William Robert. Bridge Farm, Ellenbrook, near Manchester.
1877. ‡MOUNT-EDGCUMBE, The Right Hon. the Earl of, D.C.L. Mount-Edgcumbe, Devonport.

Year of Election.

1887. ‡Moxon, Thomas B. County Bank, Manchester.
1888. ‡Moyle, R. E., B.A., F.C.S. The College, Cheltenham.
1884. ‡Moyse, C. E., B.A., Professor of English Language and Literature in McGill College, Montreal. 802 Sherbrooke-street, Montreal, Canada.
1884. ‡Moyse, Charles E. 802 Sherbrooke-street, Montreal, Canada.
1876. *Muir, Sir John, Bart. 6 Park-gardens, Glasgow.
1874. ‡MUIR, M. M. PATTISON, M.A. Caius College, Cambridge.
1876. ‡Muir, Thomas, M.A., LL.D., F.R.S.E. Beechcroft, Bothwell, Glasgow.
1872. ‡Muirhead, Alexander, D.Sc., F.C.S. 2 Prince's-street, Storey's-gate, Westminster, S.W.
1876. *Muirhead, Robert Franklin, M.A., B.Sc. Bridge of Weir, Renfrewshire.
1884. **Muirhead-Paterson, Miss Mary. Laurieville, Queen's Drive, Crosshill, Glasgow.*
1883. ‡MULHALL, MICHAEL G. Fancourt, Balbriggan, Co. Dublin.
1883. ‡Mulhall, Mrs. Marion. Fancourt, Balbriggan, Co. Dublin.
1891. §MÜLLER, F. MAX, M.A., Professor of Comparative Philology in the University of Oxford. 7 Norham-gardens, Oxford.
1884. *MÜLLER, HUGO, Ph.D., F.R.S., F.C.S. 13 Park-square East, Regent's Park, London, N.W.
1880. ‡Muller, Hugo M. 1 Grünanger-gasse, Vienna.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, The Right Hon. A. J., M.P., F.R.S., F.R.G.S. 16 Elvaston-place, London, S.W.
1876. ‡Munro, Donald, F.C.S. The University, Glasgow.
1885. ‡MUNRO, J. E. CRAWFORD, LL.D. Owens College, Manchester.
1883. *MUNRO, ROBERT, M.A., M.D. 48 Manor-place, Edinburgh.
1872. *Munster, H. Sillwood Lodge, Brighton.
1864. ‡MURCH, JEROM. Cranwells, Bath.
1864. *Murchison, K. R. Brockhurst, East Grinstead.
1855. ‡Murdoch, James B. Capelrig, Mearns, Renfrewshire.
1890. ‡Murphy, A. J. Preston House, Leeds.
1889. ‡Murphy, James, M.A., M.D. Holly House, Sunderland.
1852. ‡*Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.*
1884. §Murphy, Patrick. Newry, Ireland.
1887. ‡Murray, A. Hazeldean, Kersal, Manchester.
1869. ‡Murray, Adam. 78 Manor Road, Brockley, S.E.
1891. ‡Murray, G. R. M., F.R.S.E., F.L.S. British Museum (Natural History), South Kensington, London, S.W.
1859. ‡Murray, John, M.D. Forres, Scotland.
1884. ‡MURRAY, JOHN, F.R.S.E. 'Challenger' Expedition Office, Edinburgh.
1884. ‡Murray, J. Clark, LL.D., Professor of Logic and Mental and Moral Philosophy in McGill University, Montreal. 111 McKay-street, Montreal, Canada.
1872. ‡Murray, J. Jardine, F.R.C.S.E. 99 Montpellier-road, Brighton.
1892. ‡Murray, T. S. 1 Nelson-street, Dundee.
1863. ‡Murray, William, M.D. 34 Clayton-street, Newcastle-on-Tyne.
1883. ‡Murray, W. Vaughan. 4 Westbourne-crescent, Hyde Park, London, W.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1891. §Muybridge, Eadweard. University of Pennsylvania, Philadelphia, U.S.A.
1890. *Myres, John L., M A. Swanbourne, Winslow, Buckinghamshire.

Year of Election.

1886. §Nagel, D. H., M.A., F.C.S. Trinity College, Oxford.
1892. *Nairn, Michael B. Kirkcaldy, N.B.
1890. §Nalder, Francis Henry. 16 Red Lion-street, Clerkenwell, London, E.C.
1876. ‡Napier, James S. 9 Woodside-place, Glasgow.
1872. ‡Nares, Admiral Sir G. S., K.C.B., R.N., F.R.S., F.R.G.S. St. Bernard's, Maple-road, Surbiton.
1887. ‡Nason, Professor Henry B., Ph.D., F.C.S. Troy, New York, U.S.A.
1887. §Neild, Charles. 19 Chapel Walks, Manchester.
1883. *Neild, Theodore, B.A. Dalton Hall, Manchester.
1887. ‡Neill, Joseph S. Claremont, Broughton Park, Manchester.
1887. ‡Neill, Robert, jun. Beech Mount, Higher Broughton, Manchester.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1876. ‡*Nelson, D. M.* 11 *Bothwell-street, Glasgow.*
1886. ‡Nettlefold, Edward. 51 Carpenter-road, Edgbaston, Birmingham.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, The Right Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1889. ‡Neville, F. H. Sidney College, Cambridge.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
1889. *Newall, H. Frank. Madingley Rise, Cambridge.
1891. *Newell, W. H. A. 10 Plasturton-gardens, Cardiff.
1886. ‡Newbolt, F. G. Edenhurst, Addlestone, Surrey.
1842. *Newman, Professor Francis William. 15 Arundel-crescent, Weston-super-Mare.
1889. §Newstead, A. H. L., B.A. Roseacre, Epping.
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalene College, Cambridge.
1892. ‡Newton, E. T., F.R.S., F.G.S. Geological Museum, Jermyn-street, London, S.W.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1883. ‡Nias, Miss Isabel. 56 Montagu-square, London, W.
1882. ‡Nias, J. B., B.A. 56 Montagu-square, London, W.
1867. ‡Nicholl, Thomas. Dundee.
1875. ‡Nicholls, J. F. City Library, Bristol.
1866. ‡Nicholson, Sir Charles, Bart., M.D., D.C.L., LL.D., F.G.S., F.R.G.S. The Grange, Totteridge, Herts.
1867. ‡Nicholson, Henry Alleyne, M.D., D.Sc., F.G.S., Professor of Natural History in the University of Aberdeen.
1887. *Nicholson, John Carr. Moorfield House, Headingley, Leeds.
1884. ‡Nicholson, Joseph S., M.A., D.Sc., Professor of Political Economy in the University of Edinburgh. Eden Lodge, Newbattle-terrace, Edinburgh.
1883. ‡Nicholson, Richard, J.P. Whinfield, Hesketh Park, Southport.
1887. ‡Nicholson, Robert H. Bourchier. 21 Albion-street, Hull.
1881. ‡Nicholson, William R. Clifton, York.
1893. §Nickolls, John B., F.C.S. The Laboratory, Guernsey.
1887. ‡Nickson, William. Shelton, Sibson-road, Sale, Manchester.
1885. §Nicol, W. W. J., M.A., D.Sc., F.R.S.E. Mason Science College, Birmingham.
1878. ‡Niven, Charles, M.A., F.R.S., F.R.A.S., Professor of Natural Philosophy in the University of Aberdeen. 6 Chanonry, Aberdeen.
1886. ‡*Niven, George. Erkingholme, Coolhurst-road, London, N.*

Year of Election.

1877. ‡Niven, James, M.A. King's College, Aberdeen.
1874. ‡Nixon, Randal C. J., M.A. Royal Academical Institution, Belfast.
1884. ‡Nixon, T. Alcock. 33 Harcourt-street, Dublin.
1863. *NOBLE, Sir ANDREW, K.C.B., F.R.S., F.R.A.S., F.C.S. Elswick Works, Newcastle-upon-Tyne.
1879. ‡Noble, T. S., F.G.S. Lendal, York.
1886. ‡Nock, J. B. Mayfield, Penns, near Birmingham.
1887. ‡Nodal, John H. The Grange, Heaton Moor, near Stockport.
1870. ‡Nolan, Joseph, M.R.I.A. 14 Hume-street, Dublin.
1882. ‡Norfolk, F. 16 Carlton-road, Southampton.
1863. §NORMAN, Rev. Canon ALFRED MERLE, M.A., D.C.L., F.R.S., F.L.S. Burnmoor Rectory, Fence Houses, Co. Durham.
1888. ‡Norman, George. 12 Brock-street, Bath.
1865. ‡NORRIS, RICHARD, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. ‡Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1883. *Norris, William G. Coalbrookdale, Shropshire.
1881. ‡North, William, B.A., F.C.S. 84 Micklegate, York.
*NORTHWICK, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
NORTON, The Right Hon. Lord, K.C.M.G. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1886. ‡Norton, Lady. 35 Eaton-place, London, S.W.; and Hamshall, Birmingham.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1887. ‡Nursey, Perry Fairfax. 161 Fleet-street, London, E.C.
1883. *Nutt, Miss Lilian. Rosendale Hall, West Dulwich, London, S.E.

1882. §Obach, Eugene, Ph.D. 2 Victoria-road, Old Charlton, Kent.
O'Callaghan, George. Tallas, Co. Clare.
1878. ‡O'Conor Don, The. Clonalis, Castlerea, Ireland.
1883. ‡Odgers, William Blake, M.A., LL.D. 4 Elm-court, Temple, London, E.C.
1858. *ODLING, WILLIAM, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. 15 Norham-gardens, Oxford.
1884. ‡Odlum, Edward, M.A. Pembroke, Ontario, Canada.
1857. ‡O'Donnavan, William John. 54 Kenilworth-square, Rathgar, Dublin.
1877. ‡*Ogden, Joseph.* 13 *Hythe-villas, Limes-road, Croydon.*
1885. ‡Ogilvie, Alexander, LL.D. Gordon's College, Aberdeen.
1876. ‡Ogilvie, Campbell P. Sizewell House, Leiston, Suffolk.
1885. ‡OGILVIE, F. GRANT, M.A., B.Sc., F.R.S.E. Heriot Watt College, Edinburgh.
1893. §Ogilvie, Miss Maria M., D.Sc. Gordon's College, Aberdeen.
1859. ‡Ogilvy, Rev. C. W. Norman. Baldan House, Dundee.
*Ogle, William, M.D., M.A. The Elms, Derby.
1884. ‡O'Halloran, J. S., F.R.G.S. Royal Colonial Institute, Northumberland-avenue, London, W.C.
1881. ‡Oldfield, Joseph. Lendal, York.
1887. ‡Oldham, Charles. Syrian House, Sale, near Manchester.
1892. §Oldham, H. Yule. Lecturer in Geography in the University of Cambridge.
1853. ‡OLDHAM, JAMES, M.Inst.C.E. Cottingham, near Hull.
1885. ‡Oldham, John. River Plate Telegraph Company, Monte Video.

Year of Election.

1893. §Oldham, R. D., Geological Survey of India. Care of Messrs. H. S. King & Co., Cornhill, London, E.C.
1892. ‡Oliphant, James. 50 Palmerston-place, Edinburgh.
1863. ‡Oliver, Daniel, LL.D., F.R.S., F.L.S., Emeritus Professor of Botany in University College, London. 10 Kew Gardens-road, Kew, Surrey.
1887. ‡Oliver, F. W., D.Sc. 10 Kew Gardens-road, Kew, Surrey.
1883. ‡Oliver, J. A. Westwood. The Liberal Club, Glasgow.
1883. §Oliver, Samuel A. Bellingham House, Wigan, Lancashire.
1889. ‡Oliver, Professor T., M.D. 7 Ellison-place, Newcastle-upon-Tyne.
1882. §Olsen, O. T., F.R.A.S., F.R.G.S. 116 St. Andrew's - terrace, Grimsby.
*Ommanney, Admiral Sir Erasmus, C.B., LL.D., F.R.S., F.R.A.S., F.R.G.S. 29 Connaught-square, Hyde Park, London, W.
1880. *Ommanney, Rev. E. A. St. Mary's Vicarage, Frome, Somerset.
1887. ‡O'Neill, Charles. Glen Allan, Manley-road, Alexandra Park, Manchester.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1883. ‡Oppert, Gustav, Professor of Sanskrit. Madras.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1883. ‡Ord, Miss Maria. Fern Lea, Park-crescent, Southport.
1883. ‡Ord, Miss Sarah. Fern Lea, Park-crescent, Southport.
1880. ‡O'Reilly, J. P., Professor of Mining and Mineralogy in the Royal College of Science, Dublin.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1883. ‡Orpen, Miss. 58 Stephen's-green, Dublin.
1884. *Orpen, Major R. T., R.E. Gibraltar.
1884. *Orpen, Rev. T. H., M.A. Binnbrooke, Cambridge.
1838. Orr, Alexander Smith. 57 Upper Sackville-street, Dublin.
1873. ‡*Osborn, George. 47 Kingscross-street, Halifax.*
1887. §O'Shea, L. T., B.Sc. Firth College, Sheffield.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. Coppy Hill, Linthurst, near Bromsgrove, Birmingham.
1869. **Osler, Sidney F. Chesham Lodge, Lower Norwood, Surrey, S.E.*
1884. ‡Osler, William, M.D., Professor of the Institutes of Medicine in McGill University, Montreal, Canada.
1884. ‡O'Sullivan, James, F.C.S. 71 Spring Terrace-road, Burton-on-Trent.
1882. *Oswald, T. R. Castle Hall, Milford Haven.
1881. *Ottewell, Alfred D. 14 Sansome-street, San Francisco, U.S.A.
1882. ‡Owen, Rev. C. M., M.A. St. George's, Edgbaston, Birmingham.
1889. *Owen, Alderman H. C. Compton, Wolverhampton.
1888. *Owen, Thomas. 8 Alfred-street, Bath.
1877. ‡Oxland, Dr. Robert, F.C.S. 8 Portland-square, Plymouth.

1889. ‡Page, Dr. F. 1 Saville-place, Newcastle-upon-Tyne.
1883. ‡Page, George W. Fakenham, Norfolk.
1883. ‡Page, Joseph Edward. 12 Saunders-street, Southport.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1884. ‡Paine, Cyrus F. Rochester, New York, U.S.A.
1875. ‡Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis, F.R.S., F.S.S. Belton, Great Yarmouth.

Year of Election.

1883. ‡Palgrave, Mrs. R. H. Inglis. Belton, Great Yarmouth.
1889. ‡PALMER, Sir CHARLES MARK, Bart., M.P. Grinkle Park, Yorkshire.
1873. ‡Palmer, George, M.P. The Acacias, Reading, Berks.
1878. *Palmer, Joseph Edward. 8 Upper Mount-street, Dublin.
1887. *Palmer, Miss Mary Kate. Kilburn House, Sherwood, Notts.
1866. §Palmer, William. Kilbourne House, Cavendish Hill, Sherwood, Nottinghamshire.
1872. **Palmer, W. R. 1 The Cloisters, Temple, E.C.*
Palmes, Rev. William Lindsay, M.A. Naburn Hall, York.
1890. ‡Pankhurst, R. M., LL.D. 8 Russell-square, London, W.C.
1883. §Pant, F. J. Van der. Clifton Lodge, Kingston-on-Thames.
1886. ‡Panton, George A., F.R.S.E. 73 Westfield-road, Edgbaston, Birmingham.
1884. ‡Panton, Professor J. Hoyes, M.A., F.G.S. Ontario Agricultural College, Guelph, Ontario, Canada.
1883. ‡Park, Henry. Wigan.
1883. ‡Park, Mrs. Wigan.
1880. *Parke, George Henry, F.L.S., F.G.S. St. John's, Wakefield, Yorkshire.
1863. ‡Parker, Henry. Low Elswick, Newcastle-upon-Tyne.
1874. ‡*Parker, Henry R., LL.D. Methodist College, Belfast.*
1886. ‡Parker, Lawley. Chad Lodge, Edgbaston, Birmingham.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1891. ‡Parker, William Newton, Ph.D., F.Z.S., Professor of Biology in University College, Cardiff.
1865. *Parkes, Samuel Hickling, F.L.S. Ashfield-road, King's Heath, Birmingham.
1879. §Parkin, William. The Mount, Sheffield.
1887. §Parkinson, James. Station-road, Turton, Bolton.
1859. ‡Parkinson, Robert, Ph.D. Yewbarrow House, Grange-over-Sands.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
1883. ‡Parson, T. Cooke, M.R.C.S. Atherston House, Clifton, Bristol.
1877. ‡Parson, T. Edgcumbe. 36 Torrington-place, Plymouth.
1865. *Parsons, Charles Thomas. Norfolk-road, Edgbaston, Birmingham.
1878. ‡Parsons, Hon. C. A. Elvaston Hall, Newcastle-upon-Tyne.
1883. ‡Part, Isabella. Rudleth, Watford, Herts.
1875. ‡Pass, Alfred C. Rushmere House, Durdham Down, Bristol.
1881. §Patchitt, Edward Cheshire. 128 Derby-road, Nottingham.
1887. ‡Paterson, A. M., M.D. University College, Dundee.
1884. *Paton, David. Johnstone, Scotland.
1883. *Paton, Henry, M.A. 15 Myrtle-terrace, Edinburgh.
1884. *Paton, Hugh. 911 Sherbrooke-street, Montreal, Canada.
1883. ‡Paton, Rev. William. The Ferns, Parkside, Nottingham.
1871. *Patterson, A. Henry. 3 New-square, Lincoln's Inn, London, W.C.
1884. ‡Patterson, Edward Mortimer. Fredericton, New Brunswick, Canada.
1876. §Patterson, T. L. Maybank, Greenock.
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast.
1889. ‡*Pattinson, H. L., jun. Felling Chemical Works, Felling-upon-Tyne.*
1863. ‡PATTINSON, JOHN, F.C.S. 75 The Side, Newcastle-upon-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-upon-Tyne.
1867. ‡Pattison, Samuel Rowles, F.G.S. 11 Queen Victoria-street, London, E.C.
1879. *Patzer, F. R. Stoke-on-Trent.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1892. ‡Paul, J. Balfour. 32 Great King-street, Edinburgh.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S. 35 Grosvenor-street, London, W.

Year of Election.

1887. ‡Paxman, James. Hill House, Colchester.
1887. *Payne, Miss Edith Annie. Hatchlands, Cuckfield, Hayward's Heath.
1881. ‡Payne, J. Buxton. 15 Mosley-street, Newcastle-upon-Tyne.
1877. *Payne, J. C. Charles. Botanic-avenue, The Plains, Belfast.
1881. ‡Payne, Mrs. Botanic-avenue, The Plains, Belfast.
1866. ‡Payne, Dr. Joseph F. 78 Wimpole-street, London, W.
1888. *Paynter, J. B. Hendford Manor House, Yeovil.
1886. ‡Payton, Henry. Eversleigh, Somerset-road, Birmingham.
1876. ‡Peace, G. H. Monton Grange, Eccles, near Manchester.
1879. ‡Peace, William K. Moor Lodge, Sheffield.
1885. ‡Peach, B. N., F.R.S., F.R.S.E., F.G.S. Geological Survey Office, Edinburgh.
1883. ‡Peacock, Ebenezer. 8 Mandeville-place, Manchester-square, London, W.
1875. ‡Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.
1881. *Pearce, Horace, F.R.A.S., F.L.S., F.G.S. The Limes, Stourbridge.
1886. *Pearce, Mrs. Horace. The Limes, Stourbridge.
1888. §Pearce, Rev. R. J., D.C.L., Professor of Mathematics in the University of Durham. 7 South Bailey, Durham.
1884. ‡Pearce, William. Winnipeg, Canada.
1886. ‡Pearsall, Howard D. 19 Willow-road, Hampstead, London, N.W.
1887. ‡*Pearse, J. Walter. Brussels.*
1883. ‡Pearson, Arthur A. Colonial Office, London, S.W.
1891. ‡Pearson, B. Dowlais Hotel, Cardiff.
1893. *Pearson, Charles E. Chilwell House, Nottinghamshire.
1883. ‡Pearson, Miss Helen E. 69 Alexandra-road, Southport.
1892. ‡Pearson, J. M. John Dickie-street, Kilmarnock.
1881. ‡Pearson, John. Glentworth House, The Mount, York.
1883. ‡Pearson, Mrs. Glentworth House, The Mount, York.
1872. *Pearson, Joseph. Grove Farm, Merlin, Raleigh, Ontario, Canada.
1881. ‡Pearson, Richard. 57 Bootham, York.
1870. ‡*Pearson, Rev. Samuel, M.A. Highbury-quadrant, London, N.*
1883. *Pearson, Thomas H. Redclyffe, Newton-le-Willows, Lancashire.
1863. §Pease, H. F., M.P. Brinkburn, Darlington.
1889. ‡Pease, Howard. Enfield Lodge, Benwell, Newcastle-upon-Tyne.
1863. ‡Pease, Sir Joseph W., Bart., M.P. Hutton Hall, near Guisborough.
1863. ‡Pease, J. W. Newcastle-upon-Tyne.
1883. ‡Peck, John Henry. 52 Hoghton-street, Southport.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
*Peckover, Alexander, F.S.A., F.L.S., F.R.G.S. Bank House, Wisbech, Cambridgeshire.
1888. ‡Peckover, Miss Alexandrina. Bank House, Wisbech, Cambridgeshire.
1885. ‡Peddie, William, D.Sc., F.R.S.E. 2 Cameron Park, Edinburgh.
1884. ‡Peebles, W. E. 9 North Frederick-street, Dublin.
1883. ‡Peek, Cuthbert E. Wimbledon House, Wimbledon, Surrey.
1878. *Peek, William. The Manor House, Kemp Town, Brighton.
1881. ‡Peggs, J. Wallace. 21 Queen Anne's-gate, London, S.W.
1884. ‡Pegler, Alfred. Elmfield, Southampton.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1868. ‡Pelham, The Hon. and Right Rev. J. T., D.D. Norwich.
1878. ‡Pemberton, Charles Seaton. 44 Lincoln's Inn-fields, London, W.C.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, Sir John, G.C.M.G., M.P. 18 Arlington-street, London, S.W.
1887. §Pendlebury William H., M.A., F.C.S. 6 Gladstone-terrace, Priory Hill, Dover.

Year of
Election.

1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.
1881. ‡Penty, W. G. Melbourne-street, York.
1875. ‡Perceval, Rev. Canon John, M.A., LL.D. Rugby.
1889. ‡Percival, Archibald Stanley, M.A., M.B. 6 Lovaine-crescent, Newcastle-upon-Tyne.
*Perigal, Frederick. Cambridge Cottage, Kingswood, Reigate.
1868. *PERKIN, WILLIAM HENRY, Ph.D., F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow, Middlesex.
1884. ‡Perkin, William Henry, jun., Ph.D., F.R.S., F.C.S., Professor of Organic Chemistry in Owens College, Manchester.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1885. ‡Perrin, Miss Emily. 31 St John's Wood Park, London, N.W.
1886. ‡Perrin, Henry S. 31 St. John's Wood Park, London, N.W.
1886. ‡Perrin, Mrs. 23 Holland Villas-road, Kensington, London, W.
1879. ‡*Perry, James. Roscommon.*
1874. *PERRY, JOHN, M.E., D.Sc., F.R.S., Professor of Engineering and Applied Mathematics in the Technical College, Finsbury. 31 Brunswick-square, London, W.C.
1883. ‡Perry, Ottley L., F.R.G.S. Bolton-le-Moors, Lancashire.
1883. ‡Perry, Russell R. 34 Duke-street, Brighton.
1883. ‡Petrie, Miss Isabella. Stone Hill, Rochdale.
1871. *Peyton, John E. H., F.R.A.S., F.G.S. 23 Sillwood-road, Brighton.
1882. ‡Pfoundes, Charles. Spring Gardens, London, S.W.
1886. ‡Phelps, Colonel A. 23 Augustus-road, Edgbaston, Birmingham.
1884. ‡Phelps, Charles Edgar. Carisbrooke House, The Park, Nottingham.
1884. ‡Phelps, Mrs. Carisbrooke House, The Park, Nottingham.
1886. ‡Phelps, Hon. E. J. American Legation, Members' Mansions, Victoria-street, London, S.W.
1886. ‡Phelps, Mrs. Hamshall, Birmingham.
1863. *PHENÉ, JOHN SAMUEL, LL.D., F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1892. ‡Philip, R. W., M.D. 4 Melville-crescent, Edinburgh.
1870. ‡Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. The Oak House, Macclesfield.
1877. §Philips, T. Wishart. Lonsdale, Wanstead, Essex.
1863. ‡Philipson, Dr. 7 Eldon-square, Newcastle-upon-Tyne.
1889. ‡Philipson, John. 9 Victoria-square, Newcastle-upon-Tyne.
1883. ‡Phillips, Arthur G. 20 Canning-street, Liverpool.
1887. ‡*Phillips, H. Harcourt, F.C.S.* 18 *Exchange-street, Manchester.*
1892. §Phillips, J. H. Poole, Dorset.
1880. §Phillips, John H., Hon. Sec. Philosophical and Archæological Society, Scarborough.
1890. §Phillips, R. W., M.A., Professor of Biology in University College, Bangor.
1883. ‡Phillips, S. Rees. Wonford House, Exeter.
1881. ‡Phillips, William. 9 Bootham-terrace, York.
1868. ‡PHIPSON, T. L., Ph.D., F.C.S. 4 The Cedars, Putney, Surrey, S.W.
1884. *Pickard, Rev. H. Adair, M.A. 5 Canterbury-road, Oxford.
1883. *Pickard, Joseph William. Lindow Cottage, Lancaster.
1885. *PICKERING, SPENCER U., M.A., F.R.S., F.C.S. 48 Bryanston-square, London, W.
1884. *Pickett, Thomas E., M.D. Maysville, Mason County, Kentucky, U.S.A.
1888. *Pidgeon, W. R. 42 Porchester-square, London, W.

Year of Election.

1871. ‡Pigot, Thomas F., M.R.I.A. Royal College of Science, Dublin.
1884. ‡Pike, L. G., M.A., F.Z.S. 4 The Grove, Highgate, London, N.
1865. ‡PIKE, L. OWEN. 201 Maida-vale, London, W.
1873. ‡Pike, W. H. University College, Toronto, Canada.
1857. ‡*Pilkington, Henry M., LL.D., Q.C. 45 Upper Mount-street, Dublin.*
1883. ‡*Pilling, R. C. The Robin's Nest, Blackburn.*
Pim, George, M.R.I.A. Brenanstown, Cabinteely, Co. Dublin.
1877. ‡Pim, Joseph T. Greenbank, Monkstown, Co. Dublin.
1868. ‡Pinder, T. R. St. Andrew's, Norwich.
1876. ‡PIRIE, Rev. G., M.A., Professor of Mathematics in the University of Aberdeen. 33 College Bounds, Old Aberdeen.
1884. ‡Pirz, Anthony. Long Island, New York, U.S.A.
1887. ‡Pitkin, James. 56 Red Lion-street, Clerkenwell, London, E.C.
1875. ‡Pitman, John. Redcliff Hill, Bristol.
1883. ‡*Pitt, George Newton, M.A., M.D. 34 Ashburn-place, South Kensington, London, S.W.*
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1883. ‡Pitt, Sydney. 12 Brunswick-gardens, London, W.
1893. *Pitt, Walter, M.Inst.C.E. South Stoke House, near Bath.
1868. ‡PITT-RIVERS, Lieut.-General A. H. L., D.C.L., F.R.S., F.G.S., F.S.A. 4 Grosvenor-gardens, London, S.W.
1872. ‡*Plant, Mrs. H. W. 28 Evington-street, Leicester.*
1842. PLAYFAIR, The Right Hon. Lord, K.C.B., Ph.D., LL.D., F.R.S., F.R.S.E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1867. ‡PLAYFAIR, Lieut.-Colonel Sir R. L., K.C.M.G., H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1884. *Playfair, W. S., M.D., LL.D., Professor of Midwifery in King's College, London. 31 George-street, Hanover-square, London, W.
1883. *Plimpton, R. T., M.D. 23 Lansdowne-road, Clapham-road, London, S.W.
1893. §Plowright, Henry J., F.G.S. Brampton Foundries, Chesterfield.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Bodnant Hall, near Conway.
1881. §Pocklington, Henry. 20 Park-row, Leeds.
1888. ‡Pocock, Rev. Francis. 4 Brunswick-place, Bath.
1846. ‡POLE, WILLIAM, Mus.Doc., F.R.S., M.Inst.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1891. ‡Pomeroy, Captain Ralph. 201 Newport-road, Cardiff.
1892. §Popplewell, W. C., B.Sc. Claremont-road, Irlams-o'-th'-Height, Manchester.
1868. ‡PORTAL, WYNDHAM S. Malshanger, Basingstoke.
1883. *Porter, Rev. C. T., LL.D. Brechin Lodge, Cambridge-road, Southport.
1886. ‡*Porter, Paxton. Birmingham and Midland Institute, Birmingham.*
1883. ‡Postgate, Professor J. P., M.A. Trinity College, Cambridge.
1863. ‡Potter, D. M. Cramlington, near Newcastle-upon-Tyne.
1887. ‡Potter, Edmund P. Hollinhurst, Bolton.
1883. ‡Potter, M. C., M.A., F.L.S., Professor of Botany in the College of Science, Newcastle-upon-Tyne. 14 Portland-terrace, Newcastle-upon-Tyne.
1883. §Potts, John. Thorn Tree House, Chester-road, Macclesfield.

Year of Election.

1886. *POULTON, EDWARD B., M.A., F.R.S., F.L.S., F.Z.S., Professor of Zoology in the University of Oxford. Wykeham House, Oxford.
1873. *Powell, Sir Francis S., Bart., M.P., F.R.G.S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1887. *Powell, Horatio Gibbs. Wood Villa, Tettenhall Wood, Wolverhampton.
1883. ‡Powell, John. Waunarlwydd House, near Swansea.
1875. ‡Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1887. §Pownall, George H. Manchester and Salford Bank, Mosley-street, Manchester.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuk, Uddingston, Scotland.
1883. ‡POYNTING, J. H., D.Sc., F.R.S., Professor of Physics in the Mason College, Birmingham. 11 St. Augustine's-road, Birmingham.
1884. §Prance, Courtenay C. Hatherley Court, Cheltenham.
1884. *Prankerd, A. A., D.C.L. Brazenose College, Oxford.
1891. ‡Pratt, Bickerton. Brynderwen, Maindee, Newport, Monmouthshire.
1869. *PREECE, WILLIAM HENRY, C.B., F.R.S., M.Inst.C.E. Gothic Lodge, Wimbledon Common, Surrey.
1888. *Preece, W. Llewellyn. Telegraph Department, Midland Railway, Derby.
1884. *Premio-Real, His Excellency the Count of. Quebec, Canada.
1892. §Prentice, Thomas. Willow Park, Greenock.
1889. §Preston, Alfred Eley. 14 The Exchange, Bradford, Yorkshire.
1893. *Preston, Martin Inett. 9 St. James's-terrace, Nottingham.
1893. §PRESTON, Professor THOMAS. Trinity College, Dublin.
*PRESTWICH, JOSEPH, M.A., D.C.L., F.R.S., F.G.S., F.C.S. Shoreham, near Sevenoaks.
1884. *Prevost, Major L. de T. 2nd Battalion Argyll and Sutherland Highlanders.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., D.D., F.R.S., F.R.A.S., Master of Pembroke College, Oxford.
1882. ‡Price, John E., F.S.A. 27 Bedford-place, Russell-square, London, W.C.
Price, J. T. Neath Abbey, Glamorganshire.
1888. ‡PRICE, L. L. F. R., M.A., F.S.S. Oriel College, Oxford.
1881. ‡Price, Peter. 12 Windsor-place, Cardiff.
1875. *Price, Rees. 163 Bath-street, Glasgow.
1891. ‡Price, William. 40 Park-place, Cardiff.
1876. ‡*Priestley, John. 174 Lloyd-street, Greenheys, Manchester.*
1892. ‡Prince, Professor Edward E. St. Mungo's College, Glasgow.
1875. ‡Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1883. ‡*Prince, Thomas. Horsham-road, Dorking.*
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1889. *Pritchard, Eric Law. 12 Alwyne-place, Canonbury, London, N.
1876. *PRITCHARD, URBAN, M.D., F.R.C.S. 3 George-street, Hanover-square, London, W.
1888. ‡Probyn, Leslie C. Onslow-square, London, S.W.
1881. §Procter, John William. Ashcroft, Nunthorpe, York.
1863. ‡Proctor, R. S. Summerhill-terrace, Newcastle-upon-Tyne.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1885. ‡Profeit, Dr. Balmoral, N.B.
1863. ‡Proud, Joseph. South Hetton, Newcastle-upon-Tyne.
1884. *Proudfoot, Alexander, M.D. 2 Phillips-place, Montreal, Canada.

Year of Election.

1879. *Prouse, Oswald Milton, F.G.S., F.R.G.S. Alvington, Slade-road Ilfracombe.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. 42 Cadogan-place, London, S.W.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. *Pullar, Robert, F.R.S.E. Tayside, Perth.
1883. *Pullar, Rufus D., F.C.S. Ochil, Perth.
1891. ‡Pullen, W. W. F. University College, Cardiff.
1842. *Pumphrey, Charles. Southfield, King's Norton, near Birmingham.
1887. §PUMPHREY, WILLIAM. Lyncombe, Bath.
1885. §Purdie, Thomas, B.Sc., Ph.D., Professor of Chemistry in the University of St. Andrews. St. Andrews, N.B.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1881. ‡Purey-Cust, Very Rev. Arthur Percival, M.A., Dean of York. The Deanery, York.
1882. ‡Purrott, Charles. West End, near Southampton.
1874. ‡PURSER, FREDERICK, M.A. Rathmines, Dublin.
1866. ‡PURSER, Professor JOHN, M.A., M.R.I.A. Queen's College Belfast.
1878. ‡Purser, John Mallet. 3 Wilton-terrace, Dublin.
1884. *Purves, W. Laidlaw. 20 Stafford-place, Oxford-street, London, W.
1860. *Pusey, S. E. B. Bouverie. Pusey House, Faringdon.
1883. §Pye-Smith, Arnold. 16 Fairfield-road, Croydon.
1883. §Pye-Smith, Mrs. 16 Fairfield-road, Croydon.
1868. ‡PYE-SMITH, P. H., M.D., F.R.S. 48 Brook-street, W.; and Guy's Hospital, London, S.E.
1879. ‡Pye-Smith, R. J. 350 Glossop-road, Sheffield.
1861. *Pyne, Joseph John. The Willows, Albert-road, Southport.

1893. §Quick, James. University College, Bristol.

1870. ‡Rabbits, W. T. 6 Cadogan-gardens, London, S.W.
1887. ‡Rabone, John. Penderell House, Hamstead-road, Birmingham.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
1877. ‡Radford, George D. Mannamead, Plymouth.
1879. ‡Radford, R. Heber. Wood Bank, Pitsmoor, Sheffield.
*Radford, William, M.D. Sidmount, Sidmouth.
1855. *Radstock, The Right Hon. Lord. Mayfield, Woolston.
1888. ‡Radway, C. W. 9 Bath-street, Bath.
1887. *Ragdale, John Rowland. The Beeches, Whitefield, Manchester.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1885. ‡Ramsay, Major. Straloch, N.B.
1863. ‡RAMSAY, ALEXANDER, F.G.S. 2 Cowper-road, Acton, Middlesex, W.
1884. ‡Ramsay, George G., LL.D., Professor of Humanity in the University of Glasgow. 6 The College, Glasgow.
1884. ‡Ramsay, Mrs. G. G. 6 The College, Glasgow.
1861. ‡Ramsay, John. Kildalton, Argyllshire.
1889. ‡Ramsay, Major R. G. W. Bonnyrigg, Edinburgh.
1867. **Ramsay, W. F., M.D.* 109 *Sinclair-road, West Kensington Park, London, W.*
1876. *RAMSAY, WILLIAM, Ph.D., F.R.S., F.C.S., Professor of Chemistry in University College, London, W.C.
1883. ‡Ramsay, Mrs. 12 Arundel-gardens, London, W.
1887. ‡Ramsbottom, John. Fernhill, Alderley Edge, Cheshire.

Year of Election.

1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry. 6 Ormonde-terrace, Regent's Park, London, N.W.
1869. *Rance, H. W. Henniker, LL.D. 10 Castletown-road, West Kensington, London, S.W.
1868. *Ransom, Edwin, F.R.G.S. Ashburnham-road, Bedford.
1893. §Ransom, W. B., M.D. The Pavement, Nottingham.
1863. §RANSOM, WILLIAM HENRY, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A., M.D., F.R.S. Devisdale, Bowdon, Manchester.
Ransome, Thomas. Hest Bank, near Lancaster.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 11 Stone-buildings, Lincoln's Inn, London, W.C.
1889. §Rapkin, J. B. Sidcup, Kent.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1864. ‡Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1892. §Rathbone, Miss May. Backwood, Neston, Cheshire.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §*Rathbone, R. R. Beechwood House, Liverpool.*
1874. ‡RAVENSTEIN, E. G., F.R.G.S., F.S.S. 91 Upper Tulse-hill, London, S.W.
Rawdon, William Frederick, M.D. Bootham, York.
1889. ‡Rawlings, Edward. Richmond House, Wimbledon Common, Surrey.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., Bart., G.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1887. ‡Rawson, Harry. Earlswood, Ellesmere Park, Eccles, Manchester.
1875. §RAWSON, Sir RAWSON W., K.C.M.G., C.B., F.R.G.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1886. ‡Rawson, W. Stepney, M.A., F.C.S. 68 Cornwall-gardens, Queen's-gate, London, S.W.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., D.C.L., LL.D., Sec.R.S., F.R.A.S., F.R.G.S., Professor of Natural Philosophy in the Royal Institution, London. Terling Place, Witham, Essex.
1883. *Rayne, Charles A., M.D., M.R.C.S. Queen-street, Lancaster.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. ‡READE, THOMAS MELLARD, F.G.S. Blundellsands, Liverpool.
1884. §Readman, J. B., D.Sc., F.R.S.E. 4 Lindsay-place, Edinburgh.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1892. ‡Redgrave, Gilbert R., Assoc.M.Inst.C.E. Grove Lodge, Muswell Hill, London, N.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1889. ‡Redmayne, J. M. Harewood, Gateshead.
1889. ‡Redmayne, Norman. 26 Grey-street, Newcastle-upon-Tyne.
1888. ‡Rednall, Miss Edith E. Ashfield House, Neston, near Chester.
1890. *Redwood, Boverton, F.R.S.E., F.C.S. 4 Bishopsgate-street Within, London, E.C.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1891. ‡Reece, Lewis Thomas. Somerset House, Roath, Cardiff.
1861. ‡REED, Sir EDWARD J., K.C.B., M.P., F.R.S. 75 Harrington-gardens, London, S.W.
1889. ‡Reed, Rev. George. Bellingham Vicarage, Bardon Mill.
1891. *Reed, Thomas A. Merchants' Exchange, Cardiff.

Year of Election.

1891. §Rees, I. Treharne, M.Inst.C.E. The Elms, Penarth.
1891. ‡Rees, Samuel. West Wharf, Cardiff.
1891. ‡Rees, William. 25 Park-place, Cardiff.
1888. ‡Rees, W. L. 11 North-crescent, Bedford-square, London, W.C.
1875. ‡Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1881. §Reid, Arthur S., B.A., F.G.S. Trinity College, Glenalmond, N.B.
1883. *REID, CLEMENT, F.G.S. 28 Jermyn-street, London, S.W.
1892. ‡Reid, E. Waymouth, B.A., Professor of Physiology in University College, Dundee.
1889. ‡Reid, George, Belgian Consul. Leazes House, Newcastle-upon-Tyne.
1876. ‡Reid, James. 10 Woodside-terrace, Glasgow.
1884. ‡Reid, Rev. James, B.A. Bay City, Michigan, U.S.A.
1892. §Reid, Thomas. University College, Dundee.
1887. *Reid, Walter Francis. Fieldside, Addlestone, Surrey.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1893. §Reinach, Albert von. Frankfort.
1875. §REINOLD, A. W., M.A., F.R.S., Professor of Physical Science in the Royal Naval College, Greenwich, S.E.
1863. ‡RENALS, E. 'Nottingham Express' Office, Nottingham.
1891. §Rendell, Rev. J. R. Whinside, Accrington.
1885. ‡Rennett, Dr. 12 Golden-square, Aberdeen.
1889. *Rennie, George B. Hooley Lodge, Redhill.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1883. *Reynolds, A. H. Manchester and Salford Bank, Southport.
1871. ‡REYNOLDS, JAMES EMERSON, M.D., D.Sc., F.R.S., V.P.C.S., M.R.I.A., Professor of Chemistry in the University of Dublin. The Laboratory, Trinity College, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., LL.D., F.R.S., M.Inst.C.E., Professor of Engineering in Owens College, Manchester. 23 Lady Barn-road, Fallowfield, Manchester.
1858. §REYNOLDS, RICHARD, F.C.S. 13 Briggate, Leeds.
1887. ‡Rhodes, George W. The Cottage, Victoria Park, Manchester.
1883. ‡Rhodes, Dr. James. 25 Victoria-street, Glossop.
1890. ‡Rhodes, J. M., M.D. Ivy Lodge, Didsbury.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1877. *Rhodes, John. 360 Blackburn-road, Accrington, Lancashire.
1888. §Rhodes, John George. Warwick House, 46 St. George's-road, London, S.W.
1884. ‡Rhodes, Lieut.-Colonel William. Quebec, Canada.
1877. *Riccardi, Dr. Paul, Secretary of the Society of Naturalists. Via Stimmate, 15, Modena, Italy.
1891. ‡Richards, D. 1 St. Andrew's-crescent, Cardiff.
1891. ‡Richards, H. M. 1 St. Andrew's-crescent, Cardiff.
1889. ‡Richards, Professor T. W., Ph.D. Cambridge, Massachusetts, U.S.A.
1888. *RICHARDSON, ARTHUR, M.D. University College, Bristol.
1863. ‡RICHARDSON, Sir BENJAMIN WARD, M.A., M.D., LL.D., F.R.S. 25 Manchester-square, London, W.
1861. ‡Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. 15 Burnaby-gardens, Chiswick, London, W.
1882. §Richardson, Rev. George, M.A. The College, Winchester.
1884. *Richardson, George Straker. Isthmian Club, 150 Piccadilly, London, W.
1889. §Richardson, Hugh. Sedbergh School, Sedbergh R.S.O., Yorkshire.
1884. *Richardson, J. Clarke. Derwen Fawr, Swansea.

Year of Election.

1870. ‡Richardson, Ralph, F.R.S.E. 10 Magdala-place, Edinburgh.
1889. ‡Richardson, Thomas, J.P. 7 Windsor-terrace, Newcastle-upon-Tyne.
1881. ‡Richardson, W. B. Elm Bank, York.
1876. §Richardson, William Haden. City Glass Works, Glasgow.
1891. ‡Riches, Carlton H. 21 Dumfries-place, Cardiff.
1891. §Riches, T. Harry. 8 Park-grove, Cardiff.
1886. §Richmond, Robert. Leighton Buzzard.
1863. ‡*Richter, Otto, Ph.D.* 407 *St. Vincent-street, Glasgow.*
1868. ‡Ricketts, Charles, M.D., F.G.S. 19 Hamilton-square, Birkenhead.
1877. ‡*Ricketts, James, M.D. St. Helens, Lancashire.*
*Riddell, Major-General Charles J. Buchanan, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1883. *Rideal, Samuel, D.Sc., F.C.S., F.G.S. 41 Carlyle-square, London, S.W.
1862. ‡Ridgway, Henry Ackroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John 19 Belsize-park, Hampstead, London, N.W.
1889. ‡Ridley, Thomas D. Coatham, Redcar.
1884. ‡Ridout, Thomas. Ottawa, Canada.
1863. *Rigby, Samuel. Fern Bank, Liverpool-road, Chester.
1881. *Rigg, Arthur. 71 Warrington-crescent, London, W.
1883. *Rigg, Edward, M.A. Royal Mint, London, E.
1883. ‡*Rigg, F. F., M.A.* 32 *Queen's-road, Southport.*
1883. *Rigge, Samuel Taylor, F.S.A. Balmoral-place, Halifax.
1892. §Rintoul, D., M.A. Clifton College, Bristol.
1873. ‡Ripley, Sir Edward, Bart. Acacia, Apperley, near Leeds.
*Ripon, The Most Hon. the Marquess of, K.G., G.C.S.I., C.I.E., D.C.L., F.R.S., F.L.S., F.R.G.S. 9 Chelsea Embankment, London, S.W.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1892. ‡Ritchie, R. Peel, M.D., F.R.S.E. 1 Melville-crescent, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1889. ‡Ritson, U. A. 1 Jesmond-gardens, Newcastle-upon-Tyne.
1869. *Rivington, John. Babbicombe, near Torquay.
1888. ‡Robb, W. J. Firth College, Sheffield.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *Robbins, John, F.C.S. 57 Warrington-crescent, Maida Vale, London, W.
1878. ‡Roberts, Charles, F.R.C.S. 2 Bolton-row, London, W.
1887. *Roberts, Evan. Thorncliffe, 5 York-road, Southport.
1859. ‡Roberts, George Christopher. Hull.
1870. *Roberts, Isaac, D.Sc., F.R.S., F.R.A.S., F.G.S. Starfield, Crowborough, Sussex.
1891. ‡Roberts, Rev. J. Crossby, F.R.G.S. 41 Derby-road, East Park, Northampton.
1881. ‡Roberts, R. D., M.A., D.Sc., F.G.S. 17 Charterhouse-square, London, E.C.
1879. ‡Roberts, Samuel. The Towers, Sheffield.
1879. ‡Roberts, Samuel, jun. The Towers, Sheffield.
1883. ‡Roberts, Sir William, M.D., F.R.S. 8 Manchester-square, London, W.
1868. *Roberts-Austen, W. Chandler, C.B., F.R.S., F.C.S., Chemist to the Royal Mint, and Professor of Metallurgy in the Royal College of Science, London. Royal Mint, London, E.
1883. ‡Robertson, Alexander. Montreal, Canada.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1884. ‡Robertson, E. Stanley, M.A. 43 Waterloo-road, Dublin.

Year of Election.

1871. ‡Robertson, George, M.Inst.C.E., F.R.S.E. Athenæum Club, London, S.W.
1883. ‡Robertson, George H. Plas Newydd, Llangollen.
1883. ‡Robertson, Mrs. George H. Plas Newydd, Llangollen.
1876. ‡Robertson, R. A. Newthorn, Ayton-road, Pollokshields, Glasgow.
1892. ‡Robertson, W. W. 3 Parliament-square, Edinburgh.
1888. *Robins, Edward Cookworthy, F.S.A. 8 Marlborough-road, St. John's Wood, London, N.W.
1886. *Robinson, C. R. 27 Elvetham-road, Birmingham.
1886. ‡*Robinson, Edward E. 56 Dovey-street, Liverpool.*
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Beech Hill, Armagh.
1887. ‡Robinson, Henry. 7 Westminster-chambers, London, S.W.
1887. ‡Robinson, James. Akroydon Villa, Halifax, Yorkshire.
1861. ‡ROBINSON, JOHN, M.Inst.C.E. Atlas Works, Manchester.
1888. ‡Robinson, John. Engineer's Office, Barry Dock, Cardiff.
1863. ‡Robinson, J. H. 6 Montallo-terrace, Barnard Castle.
1878. ‡Robinson, John L. 198 Great Brunswick-street, Dublin.
1876. ‡Robinson, M. E. 6 Park-circus, Glasgow.
1887. §Robinson, Richard. Bellfield Mill, Rochdale.
1881. ‡Robinson, Richard Atkinson. 195 Brompton-road, London, S.W.
1875. *Robinson, Robert, M.Inst.C.E., F.G.S. Beechwood, Darlington.
1884. ‡Robinson, Stillman. Columbus, Ohio, U.S.A.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1891. §Robinson, William, Assoc.M.Inst.C.E., Professor of Engineering in University College, Nottingham.
1888. ‡Robottom, Arthur. 3 St. Alban's-villas, Highgate-road, London, N.W.
1870. *Robson, E. R. Palace Chambers, 9 Bridge-street, Westminster, S.W.
1876. ‡*Robson, Hazleton R. 14 Royal-crescent West, Glasgow.*
1872. *Robson, William. Marchholm, Gillsland-road, Merchiston, Edinburgh.
1885. *Rodger, Edward. 1 Clairmont-gardens, Glasgow.
1885. *Rodriguez, Epifanio. 12 John-street, Adelphi, London, W.C.
1866. ‡Roe, Sir Thomas, M.P. Grove-villas, Litchurch.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1890. *Rogers, L. J., M.A., Professor of Mathematics in Yorkshire College, Leeds. 13 Beech Grove-terrace, Leeds.
1883. ‡Rogers, Major R. Alma House, Cheltenham.
1882. §Rogers, Rev. Saltren, M.A. Gwennap, Redruth, Cornwall.
1884. *Rogers, Walter M. Lamowa, Falmouth.
1889. ‡Rogerson, John. Croxdale Hall, Durham.
1876. ‡ROLLIT, Sir A. K., M.P., B.A., LL.D., D.C.L., F.R.A.S., Hon. Fellow K.C.L. Thwaite House, Cottingham, East Yorkshire.
1876. ‡ROMANES, GEORGE JOHN, M.A., LL.D., F.R.S., F.L.S. 94 St. Aldate's, Oxford.
1892. *Romanes, John. 3 Oswald-road, Edinburgh.
1891. ‡Rönnfeldt, W. 43 Park-place, Cardiff.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clarke Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1881. *Roper, W. O. Eadenbreck, Lancaster.
1855. *ROSCOE, Sir HENRY ENFIELD, B.A., Ph.D., LL.D., D.C.L., M.P., F.R.S., F.C.S. 10 Bramham-gardens, London, S.W.
1883. *Rose, J. Holland, M.A. 25 Dalebury-road, Upper Tooting, London, S.W.
1892. ‡Rose, Hugh. Kilravock Lodge, Blackford-avenue, Edinburgh.

Year of Election.

1885. ‡Ross, Alexander. Riverfield, Inverness.
1874. ‡Ross, Alexander Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡*Ross, David, LL.D. 32 Nelson-street, Dublin.*
1887. ‡Ross, Edward. Marple, Cheshire.
1880. ‡Ross, Captain G. E. A., F.R.G.S. 8 Collingham-gardens, Cromwell-road, London, S.W.
1859. *Ross, Rev. James Coulman. Wadworth Hall, Doncaster.
1869. *ROSSE, The Right Hon. the Earl of, K.P., B.A., D.C.L., LL.D., F.R.S., F.R.A.S., M.R.I.A. Birr Castle, Parsonstown, Ireland.
1891. §Roth, H. Ling. 32 Prescott-street, Halifax, Yorks.
1893. §Rothera, G. B. 11 Crick-road, Oxford.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1876. ‡Rottenburgh, Paul. 13 Albion-crescent, Glasgow.
1884. *Rouse, M. L. 343 Church-street, Toronto, Canada.
1861. †ROUTH, EDWARD J., M.A., D.Sc., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1861. ‡Rowan, David. Elliot-street, Glasgow.
1883. ‡Rowan, Frederick John. 134 St. Vincent-street, Glasgow.
1887. ‡Rowe, Rev. Alfred W., M.A., F.G.S. Felstead, Essex.
1881. ‡Rowe, Rev. G. Lord Mayor's Walk, York.
1865. ‡Rowe, Rev. John. 13 Hampton-road, Forest Gate, Essex.
1877. ‡ROWE, J. BROOKING, F.L.S., F.S.A. 16 Lockyer-street, Plymouth.
1890. ‡Rowley, Walter, F.S.A. Alderhill, Meanwood, Leeds.
1881. *Rowntree, Joseph. 37 St. Mary's, York.
1881. *ROWNTREE, J. S. The Mount, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1876. ‡Roxburgh, John. 7 Royal Bank-terrace, Glasgow.
1883. ‡Roy, Charles S., M.D., F.R.S., Professor of Pathology in the University of Cambridge. Trinity College, Cambridge.
1885. ‡Roy, John. 33 Belvidere-street, Aberdeen.
1888. ‡Roy, Parbati Churn, B.A. Calcutta, Bengal, India.
1875. *RÜCKER, A. W., M.A., F.R.S., Professor of Physics in the Royal College of Science, London. (GENERAL TREASURER.) 19 Gledhow-gardens, South Kensington, London, S.W.
1892. §Rücker, Mrs. Levetleigh, Dane-road, St. Leonard's-on-Sea.
1869. §RUDLER, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1882. ‡Rumball, Thomas, M.Inst.C.E. 8 Queen Anne's-gate, London, S.W.
1884. ‡Runtz, John. Linton Lodge, Lordship-road, Stoke Newington, London, N.
1887. §Ruscoe, John, F.G.S. Ferndale, Gee Cross, near Manchester.
1847. ‡RUSKIN, JOHN, M.A., D.C.L., F.G.S. Brantwood, Coniston, Ambleside.
1889. ‡Russell, The Right Hon. Earl. Amberley Cottage, Maidenhead.
1875. *Russell, The Hon. F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1884. ‡Russell, George. 13 Church-road, Upper Norwood, London, S.E.
1890. ‡Russell, J. A., M.B. Woodville, Canaan-lane, Edinburgh.
1883. *Russell, J. W. 10 Fyfield-road, Oxford.
Russell, John. 39 Mountjoy-square, Dublin.
1852. *Russell, Norman Scott. Arts Club, Hanover-square, London, W.
1876. ‡Russell, R., F.G.S. 1 Sea View, St. Bees, Carnforth.
1886. †Russell, Thomas H. 3 Newhall-street, Birmingham.

Year of Election.

1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Lecturer on Chemistry in St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1886. ‡Rust, Arthur. Eversleigh, Leicester.
1883. *Ruston, Joseph. Monk's Manor, Lincoln.
1889. ‡Rutherford, Rev. Dr. 6 Eldon-square, Newcastle-upon-Tyne.
1891. §Rutherford, George. Garth House, Taff's Well, Cardiff.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
1887. ‡Rutherford, William. 7 Vine-grove, Chapman-street, Hulme, Manchester.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1879. ‡Ruxton, Vice-Admiral Fitzherbert, R.N., F.R.G.S. 41 Cromwell-gardens, London, S.W.
1875. ‡Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1889. ‡Ryder, W. J. H. 52 Jesmond-road, Newcastle-upon-Tyne.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

1883. ‡Sadler, Robert. 7 Lulworth-road, Birkdale, Southport.
1871. ‡Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1885. §Saint, W. Johnston. 11 Queen's-road, Aberdeen.
1866. *ST. ALBANS, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1886. §St. Clair, George, F.G.S. 225 Castle-road, Cardiff.
1881. ‡Salkeld, William. 4 Paradise-terrace, Darlington.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., LL.D., F.R.S., Provost of Trinity College, Dublin.
1883. ‡Salmond, Robert G. The Nook, Kingswood-road, Upper Norwood, S.E.
1873. *Salomons, Sir David, Bart. Broomhill, Tunbridge Wells.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Hawksfold, Haslemere.
1887. ‡Samson, C. L. Carmona, Kersal, Manchester.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1883. ‡*Sandeman, E. 53 Newton-street, Greenock.*
1878. ‡Sanders, Alfred, F.L.S. 2 Clarence-place, Gravesend, Kent.
1883. *Sanders, Charles J. B. Pennsylvania, Exeter.
1884. ‡Sanders, Henry. 185 James-street, Montreal, Canada.
1883. ‡Sanderson, Deputy Surgeon-General Alfred. East India United Service Club, St. James's-square, London, S.W.
1872. §SANDERSON, J. S. BURDON, M.A., M.D., D.Sc., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Physiology in the University of Oxford. (PRESIDENT.) 64 Banbury-road, Oxford.
1883. ‡Sanderson, Mrs. Burdon. 64 Banbury-road, Oxford.
1893. §Sanderson, Oundle. 9 The Ropewalk, Nottingham.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1892. §Sang, William D. 28 Whyte's Causeway, Kirkcaldy, Fife.
1886. §Sankey, Percy E. Hill House, Lyndhurst, Hants.
1886. ‡Sauborn, John Wentworth. Albion, New York, U.S.A.
1886. ‡Saundby, Robert, M.D. 83A Edmund-street, Birmingham.
1868. ‡Saunders, A., M.Inst.C.E. King's Lynn.
1886. ‡Saunders, C. T. Temple-row, Birmingham.
1881. ‡SAUNDERS, HOWARD, F.L.S., F.Z.S. 7 Radnor-place, London, W.
1883. ‡Saunders, Rev. J. C. Cambridge.

Year of Election.

1846. ‡SAUNDERS, TRELAWNEY W., F.R.G.S. 3 Elmfield on the Knowles, Newton Abbot, Devon.
1884. ‡Saunders, William. Experimental Farm, Ottawa, Canada.
1891. ‡Saunders, W. H. R. Llanishen, Cardiff.
1884. ‡Saunderson, C. E. 26 St. Famille-street, Montreal, Canada.
1887. §Savage, Rev. E. B., M.A., F.S.A. St. Thomas' Parsonage, Douglas, Isle of Man.
1871. ‡Savage, W. D. Ellerslie House, Brighton.
1883. ‡Savage, W. W. 109 St. James's-street, Brighton.
1883. ‡Savery, G. M., M.A. The College, Harrogate.
1872. *Sawyer, George David. 55 Buckingham-place, Brighton.
1887. §SAYCE, Rev. A. H., M.A., D.D. Queen's College, Oxford.
1884. ‡Sayre, Robert H. Bethlehem, Pennsylvania, U.S.A.
1883. *Scarborough, George. Holly Bank, Halifax, Yorkshire.
1884. ‡Scarth, William Bain. Winnipeg, Manitoba, Canada.
1879. *SCHÄFER, E. A., F.R.S., M.R.C.S., Professor of Physiology in University College, London. Croxley Green, Rickmansworth.
1883. ‡Schäfer, Mrs. Croxley Green, Rickmansworth.
1888. §SCHARFF, ROBERT F., Ph.D., B.Sc., Keeper of the Natural History Department, Museum of Science and Art, Dublin.
1880. *Schemmann, Louis Carl. Hamburg. (Care of Messrs. Allen Everitt & Sons, Birmingham.)
1892. ‡Schloss, David F. 1 Knaresborough-place, London, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1887. ‡Schofield, T. Thornfield, Talbot-road, Old Trafford, Manchester.
1883. ‡Schofield, William. Alma-road, Birkdale, Southport.
1885. §Scholes, L. Eden-terrace, Harriet-street, Stretford, near Manchester.
1888. ‡*Scholey, J. Cranefield.* 30 *Sussex-villas, Kensington, London, W.*
SCHUNCK, EDWARD, Ph.D., F.R.S., F.C.S. Oaklands, Kersal Moor, Manchester.
1873. *SCHUSTER, ARTHUR, Ph.D., F.R.S., F.R.A.S., Professor of Physics in the Owens College, Manchester.
1887. ‡Schwabe, Colonel G. Salis. Portland House, Higher Crumpsall, Manchester.
1847. *SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., F.G.S., F.R.G.S., Sec.Z.S. 3 Hanover-square, London, W.
1883. *SCLATER, WILLIAM LUTLEY, M.A., F.Z.S. Eton College, Windsor.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1881. *Scott, Alexander, M.A., D.Sc. University Chemical Laboratory, Cambridge.
1882. ‡Scott, Colonel A. de C., R.E. Ordnance Survey Office, Southampton.
1878. *Scott, Arthur William, M A., Professor of Mathematics and Natural Science in St. David's College, Lampeter.
1881. §Scott, Miss Charlotte Angus. Lancashire College, Whalley Range, Manchester.
1889. §SCOTT, D. H., M.A., Ph.D., F.L.S. The Old Palace, Richmond, Surrey.
1885. ‡Scott, George Jamieson. Bayview House, Aberdeen.
1886. ‡*Scott, Robert.* 161 *Queen Victoria-street, London, E.C.*
1857. *SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.R.Met.S., Secretary to the Council of the Meteorological Office. 6 Elm Park-gardens, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1884. *Scott, Sydney C. 15 Queen-street, Cheapside, London, E.C.
1869. ‡Scott, William Bower. Chudleigh, Devon

Year of Election.

1881. *Scrivener, A. P. Haglis House, Wendover.
1883. ‡Scrivener, Mrs. Haglis House, Wendover.
1890. §Searle, G. F. C., B.A. Peterhouse, Cambridge.
1859. ‡Seaton, John Love. The Park, Hull.
1880. ‡SEDGWICK, ADAM, M.A., F.R.S. Trinity College, Cambridge.
1880. ‡SEEBOHM, HENRY, F.R.G.S., F.L.S., F.Z.S. 22 Courtfield-gardens, London, S.W.
1861. *SEELEY, HARRY GOVIER, F.R.S., F.L.S., F.G.S., F.R.G.S., F.Z.S., Professor of Geography in King's College, London. 25 Palace Gardens-terrace, Kensington, London, W.
1893. §SELBY-BIGGE, L. A., M.A. University College, Oxford.
1891. ‡Selby, Arthur L., M.A., Assistant Professor of Physics in University College, Cardiff.
1855. ‡Seligman, H. L. 27 St. Vincent-place, Glasgow.
1879. ‡Selim, Adolphus. 21 Mincing-lane, London, E.C.
1885. §Semple, Dr. A. United Service Club, Edinburgh.
1887. §Semple, James C., F.R.G.S., M.R.I.A. 2 Marine-terrace, Kingstown, Co. Dublin.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.
1892. ‡Semple, William. Gordon's College, Aberdeen.
1888. §SENIER, ALFRED, M.D., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
1858. *Senior, George. Old Whittington, Chesterfield.
1888. *Sennett, Alfred R., A.M.Inst.C.E. Temple-chambers, Victoria Embankment, London, E.C.
1870. *Sephton, Rev. J. 90 Huskisson-street, Liverpool.
1892. §Seton, Miss Jane. 37 Candlemaker-row, Edinburgh.
1883. ‡*Seville, Miss M. A. Blythe House, Southport.*
1875. ‡*Seville, Thomas. Blythe House, Southport.*
1892. ‡Seward, A. C., M.A., F.G.S. 33 Chesterton-road, Cambridge.
1891. ‡Seward, Edwin. 55 Newport-road, Cardiff.
1868. ‡Sewell, Philip E. Catton, Norwich.
1891. ‡Shackell, E. W. 191 Newport-road, Cardiff.
1888. ‡Shackles, Charles F. Hornsea, near Hull.
1883. ‡Shadwell, John Lancelot. 17 St. Charles-square, Ladbroke Grove-road, London, W.
1871. *Shand, James. Parkholme, Elm Park-gardens, London, S.W.
1867. ‡Shanks, James. Dens Iron Works, Arbroath, N.B.
1881. ‡Shann, George, M.D. Petergate, York.
1869. *Shapter, Dr. Lewis, LL.D. 1 Barnfield-crescent, Exeter.
1878. ‡SHARP, DAVID, M.A., M.B., F.R.S., F.L.S. Museum of Zoology, Cambridge.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1886. ‡Sharp, T. B. French Walls, Birmingham.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
1883. ‡Sharples, Charles H., F.C.S. 7 Fishergate, Preston.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1887. *Shaw, James B. Holly Bank, Cornbrook, Manchester.
1870. ‡Shaw, John. 21 St. James's-road, Liverpool.
1891. ‡Shaw, Joseph. 1 Temple-gardens, London, E.C.
1889. *Shaw, Mrs. M. S., B.Sc. Halberton, near Tiverton, Devon.
1887. §Shaw, Saville, F.C.S. College of Science, Newcastle-upon-Tyne.
1883. *SHAW, W. N., M.A., F.R.S. Emmanuel House, Cambridge.
1883. ‡Shaw, Mrs. W. N. Emmanuel House, Cambridge.

Year of Election.

1891. ‡Sheen, Dr. Alfred. 23 Newport-road, Cardiff.
1884. ‡Sheldon, Professor J. P. Downton College, near Salisbury.
1878. ‡Shelford, William, M.Inst.C.E. 35A Great George-street, Westminster, S.W.
1865. ‡Shenstone, Frederick S. Sutton Hall, Barcombe, Lewes.
1881. ‡SHENSTONE, W. A. Clifton College, Bristol.
1885. ‡Shepherd, Rev. Alexander. Ecclesmechen, Uphall, Edinburgh.
1885. ‡Shepherd, Charles. 1 Wellington-street, Aberdeen.
1890. ‡Shepherd, J. Care of J. Redmayne, Esq., Grove House, Headingley, Leeds.
1883. ‡Shepherd, James. Birkdale, Southport.
1883. ‡Sherlock, David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Mrs. David. Rahan Lodge, Tullamore, Dublin.
1883. ‡Sherlock, Rev. Edgar. Bentham Rectory, *viâ* Lancaster.
1888. *Shickle, Rev. C. W., M.A. Langridge Rectory, Bath.
1886. ‡Shield, Arthur H. 35A Great George-street, London, S.W.
1892. ‡Shields, John, B.Sc., Ph.D. Dolphingston, Tranent, Scotland.
1883. *Shillitoe, Buxton, F.R.C.S. 2 Frederick-place, Old Jewry, London, E.C.
1867. ‡Shinn, William C. 39 Varden's-road, Clapham Junction, Surrey, S.W.
1887. *SHIPLEY, ARTHUR E., M.A. Christ's College, Cambridge.
1889. ‡Shipley, J. A. D. Saltwell Park, Gateshead.
1885. ‡Shirras, G. F. 16 Carden-place, Aberdeen.
1883. ‡Shone, Isaac. Pentrefelin House, Wrexham.
1870. *SHOOLBRED, JAMES N., M.Inst.C.E., F.G.S. 47 Victoria-street, London, S.W.
1888. ‡Shoppee, C. H. 22 John-street, Bedford-row, London, W.C.
1888. §Shoppee, G. A., M.A., LL.D. 61 Doughty-street, London, W.C.
1875. ‡SHORE, THOMAS W., F.C.S., F.G.S. Hartley Institution, Southampton.
1882. ‡SHORE, T. W., M.D., B.Sc., Lecturer on Comparative Anatomy at St. Bartholomew's Hospital.
1889. ‡Sibley, Walter K., B.A., M.B. 7 Harley-street, London, W.
1883. ‡Sibly, Miss Martha Agnes. Flook House, Taunton.
1883. *Sidebotham, Edward John. Erlesdene, Bowdon, Cheshire.
1883. *Sidebotham, James Nasmyth. Parkfield, Altrincham, Cheshire.
1877. *Sidebotham, Joseph Watson, M.P. Erlesdene, Bowdon, Cheshire.
1885. *SIDGWICK, HENRY, M.A., Litt.D., D.C.L., Professor of Moral Philosophy in the University of Cambridge. Hillside, Chesterton-road, Cambridge.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 7 Airlie-gardens, Campden Hill, London, W.
1878. ‡SIGERSON, Professor GEORGE, M.D., F.L.S., M.R.I.A. 3 Clare-street, Dublin.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1874. ‡Simms, William. The Linen Hall, Belfast.
1876. ‡Simon, Frederick. 24 Sutherland-gardens, London, W.
1887. *Simon, Henry. Darwin House, Didsbury, near Manchester.
1847. ‡Simon, Sir John, K.C.B., D.C.L., F.R.S., F.R.C.S., Consulting Surgeon to St. Thomas's Hospital. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1893. §Simpson, A. H., F.R.Met.Soc. Attenborough, Nottinghamshire.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.

Year of Election.

1883. ‡Simpson, Byron R. 7 York-road, Birkdale, Southport.
1887. ‡Simpson, F. Estacion Central, Buenos Ayres.
1859. ‡Simpson, John. Maykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., LL.D., F.R.S., F.C.S., 9 Barton-street, West Kensington, London, W.
1883. ‡Simpson, Walter M. 7 York-road, Birkdale, Southport.
Simpson, William. Bradmore House, Hammersmith, London, W.
1887. ‡Sinclair, Dr. 268 Oxford-street, Manchester.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1870. *Sinclair, W. P. Rivelyn, Prince's Park, Liverpool.
1864. *Sircar, The Hon. Mohendra Lal, M.D., C.I.E. 51 Sankaritola, Calcutta.
1892. §Sisley, Richard, M.D. 11 York-street, Portman-square, London, W.
1879. ‡Skertchly, Sydney B. J., F.G.S. 3 Loughborough-terrace, Carshalton, Surrey.
1883. ‡Skillicorne, W. N. 9 Queen's-parade, Cheltenham.
1885. ‡Skinner, Provost. Inverurie, N.B.
1892. ‡Skinner, William. 35 George-square, Edinburgh.
1888. §SKRINE, H. D., J.P., D.L. Claverton Manor, Bath.
1870. §SLADEN, WALTER PERCY, F.G.S., F.L.S. 13 Hyde Park-gate, London, S.W.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1889. §Slater, Matthew B., F.L.S. Malton, Yorkshire.
1884. ‡Slattery, James W. 9 Stephen's-green, Dublin.
1877. ‡Sleeman, Rev. Philip, L.Th., F.R.A.S., F.G.S. Clifton, Bristol.
1891. §Slocombe, James. Redland House, Fitzalan, Cardiff.
1884. ‡Slooten, William Venn. Nova Scotia, Canada.
1849. ‡Sloper, George Elgar. Devizes.
1887. §Small, E. W., M.A., F.G.S. County Council Offices, Newport, Monmouthshire.
1887. §Small, William. Cavendish-crescent North, The Park, Nottingham.
1881. ‡Smallshan, John. 81 Manchester-road, Southport.
1885. §Smart, James. Valley Works, Brechin, N.B.
1889. *Smart, William, LL.D. Nunholme, Dowanhill, Glasgow.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1876. ‡Smellie, Thomas D. 213 St. Vincent-street, Glasgow.
1877. ‡Smelt, Rev. Maurice Allen, M.A., F.R.A.S. Heath Lodge, Cheltenham.
1890. §Smethurst, Charles. Palace House, Harpurhey, Manchester.
1876. ‡Smieton, James. Panmure Villa, Broughty Ferry, Dundee.
1876. ‡Smieton, John G. 3 Polworth-road, Coventry Park, Streatham, London, S.W.
1867. ‡Smieton, Thomas A. Panmure Villa, Broughty Ferry, Dundee.
1892. ‡SMITH, ADAM GILLIES, F.R.S.E. 35 Drumsheugh-gardens, Edinburgh.
1892. ‡Smith, Alexander, B.Sc., Ph.D., F.R.S.E. Wabash College, Crawfordsville, Indiana, U.S.A.
1857. ‡Smith, Aquilla, M.D., M.R.I.A. 121 Lower Baggot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead Heath, London, N.W.
1874. *Smith, Benjamin Leigh, F.R.G.S. Oxford and Cambridge Club, Pall Mall, London, S.W.
1887. ‡Smith, Bryce. Rye Bank, Chorlton-cum-Hardy, Manchester.
1873. ‡Smith, C. Sidney College, Cambridge.
1887. *Smith, Charles. 739 Rochdale-road, Manchester.

Year of Election.

1889. *Smith, Professor C. Michie, B.Sc., F.R.S.E., F.R.A.S. The Observatory, Madras.
1865. ‡Smith, David, F.R.A.S. 40 Bennett's-hill, Birmingham.
1886. ‡Smith, Edwin. 33 Wheeley's-road, Edgbaston, Birmingham.
1886. *Smith, Mrs. Emma. Hencotes House, Hexham.
1886. ‡Smith, E. Fisher, J.P. The Priory, Dudley.
1886. ‡Smith, E. O. Council House, Birmingham.
1892. ‡Smith, E. Wythe. 66 College-street, Chelsea, London, S.W.
1866. *Smith, F. C. Bank, Nottingham.
1887. §Smith, Rev. F. J., M.A. Trinity College, Oxford.
1892. ‡Smith, Rev. Frederick. 16 Grafton-street, Glasgow.
1885. ‡Smith, Rev. G. A., M.A. 91 Fountainhall-road, Aberdeen.
1860. *Smith, Heywood, M.A., M.D. 18 Harley-street, Cavendish-square, London, W.
1870. ‡Smith, H. L. Crabwall Hall, Cheshire.
1889. *Smith, H. Llewellyn, B.A., B.Sc., F.S.S. 49 Beaumont-square, London, E.
1888. ‡Smith, H. W. Owens College, Manchester.
1885. ‡Smith, Rev. James, B.D. Manse of Newhills, N.B.
1876. *Smith, J. Guthrie. 54 West Nile-street, Glasgow.
Smith, John Peter George. Sweyney Cliff, Coalport, Iron Bridge, Shropshire.
1871. ‡Smith, J. William Robertson, M.A., Lord Almoner's Professor of Arabic in the University of Cambridge.
1883. ‡Smith, M. Holroyd. Fern Hill, Halifax.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1885. ‡Smith, Robert H., M.Inst.C.E., Professor of Engineering in the Mason Science College, Birmingham.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. ‡Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas. Dundee.
1867. ‡Smith, Thomas. Poole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hornsea Burton, East Yorkshire.
1884. ‡Smith, Vernon. 127 Metcalfe-street, Ottawa, Canada.
1892. ‡Smith, Walter A. 120 Princes-street, Edinburgh.
1885. *Smith, Watson. University College, London, W.C.
1887. ‡Smith, Dr. Wilberforce. 14 Stratford-place, London, W.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1875. *Smith, William. Sundon House, Clifton, Bristol.
1876. ‡Smith, William. 12 Woodside-place, Glasgow.
1883. ‡Smithells, Arthur, B.Sc., Professor of Chemistry in the Yorkshire College, Leeds.
1883. ‡Smithson, Edward Walter. 13 Lendal, York.
1883. ‡Smithson, Mrs. 13 Lendal, York.
1892. §Smithson, G. E. T. Tyneside Geographical Society, Barras Bridge, Newcastle-upon-Tyne.
1882. §Smithson, T. Spencer. Facit, Rochdale.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *Smyth, Charles Piazzi, F.R.S.E., F.R.A.S. Clova, Ripon.
1883. ‡Smyth, Rev. Christopher. Firwood, Chalford, Stroud.
1874. ‡Smyth, Henry. Eastern Villa, Newcastle, Co. Down, Ireland.
1857. *Smyth, John, jun., M.A., F.C.S., F.R.M.S., M.Inst.C.E.I. Milltown, Banbridge, Ireland.
1888. *Snape, H. Lloyd, D.Sc., Ph.D., F.C.S., Professor of Chemistry in University College, Aberystwith.

Year of Election.

1888. ‡Snell, Albion T. Brightside, Salusbury-road, Brondesbury, London, N.W.
1887. ‡Snell, Rev. Bernard J., M.A. 5 Park-place, Broughton, Manchester.
1878. §Snell, H. Saxon. 22 Southampton-buildings, London, W.C.
1889. ‡Snell, W. H. Lamorna, Oxford-road, Putney, S.W.
1879. *SOLLAS, W. J., M.A., D.Sc., F.R.S., F.R.S.E., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1892. *Somervail, Alexander. Torquay.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, LL.D., F.R.S., F.G.S. Broomfield, Sheffield.
1879. *Sorby, Thomas W. Storthfield, Sheffield.
1892. ‡Sorley, James, F.R.S.E. 18 Magdala-crescent, Edinburgh.
1888. ‡Sorley, Professor W. R. University College, Cardiff.
1886. ‡Southall, Alfred. Carrick House, Richmond Hill-road, Birmingham.
1865. *Southall, John Tertius. Parkfields, Ross, Herefordshire.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1887. §Sowerbutts, Eli, F.R.G.S. 44 Brown-street, Manchester.
1883. ‡Spanton, William Dunnett, F.R.C.S. Chatterley House, Hanley Staffordshire.
1890. ‡Spark, F. R. 29 Hyde-terrace, Leeds.
1863. *Spark, H. King, F.G.S. Startforth House, Barnard Castle.
1893. *Speak, John. Kirton Grange, Kirton, near Boston.
1889. ‡Spence, Faraday. 67 Grey-street, Hexham.
1869. **Spence, J. Berger.* 31 *Lombard-street, London, E.C.*
1887. ‡Spencer, F. M. Fernhill, Knutsford.
1884. §Spencer, John, M.Inst.M.E. Globe Tube Works, Wednesbury.
1889. *Spencer, John. Newburn, Newcastle-upon-Tyne.
1891. *Spencer, Richard Evans. 6 Working-street, Cardiff.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1864. *Spicer, Henry, B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1878. §Spottiswoode, George Andrew. 3 Cadogan-square, London, S.W.
1864. *Spottiswoode, W. Hugh, F.C.S. 41 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND, M.A., LL.D., F.R.S.E. 26 St. Andrew-square, Edinburgh.
1883. ‡Spratling, W. J., B.Sc., F.G.S. Maythorpe, 74 Wickham-road, Brockley, S.E.
1888. ‡Spreat, John Henry. Care of Messrs. Vines & Froom, 75 Aldersgate-street, London, E.C.
1884. *Spruce, Samuel, F.G.S. Beech House, Tamworth.
1877. ‡SQUARE, WILLIAM, F.R.C.S., F.R.G.S. 4 Portland-square, Plymouth.
*Squire, Lovell. 6 Heathfield-terrace, Chiswick, Middlesex.
1888. *Stacy, J. Sargeant. 7 and 8 Paternoster-row, London, E.C.
1884. ‡Stancoffe, Frederick. Dorchester-street, Montreal, Canada.
1892. ‡Stanfield, Richard, Assoc.M.Inst.C.E., F.R.S.E., Professor of Engineering in the Heriot Watt College, Edinburgh. 49 Mayfield-road, Edinburgh.
1883. *Stanford, Edward, jun., F.R.G.S. Thornbury, Bromley, Kent.
1865. ‡STANFORD, EDWARD C. C., F.C.S. Glenwood, Dalmuir, N.B.
1881. *Stanley, William Ford, F.G.S. Cumberlow, South Norwood, Surrey, S.E.

Year of Election.

1883. ‡Stanley, Mrs. Cumberlow, South Norwood, Surrey, S.E.
1893. §Staples, Sir Nathaniel. Lisson, Cookstown, Ireland.
Stapleton, M. H., M.B., M.R.I.A. 1 Mountjoy-place, Dublin.
1883. ‡Stapley, Alfred M. Marion-terrace, Crewe.
1876. ‡Starling, John Henry, F.C.S. 3 Victoria-road, Old Charlton, Kent.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. Saltaire, Shipley, Yorkshire.
1881. ‡Stead, W. H. Orchard-place, Blackwall, London, E.
1881. ‡Stead, Mrs. W. H. Orchard-place, Blackwall, London, E.
1884. ‡Stearns, Sergeant P. U.S. Consul-General, Montreal, Canada.
1892. §Stebbing, Rev. Thomas R. R., M.A. Ephraim Lodge, The Common, Tunbridge Wells.
1891. ‡Steeds, A. P. 15 St. Helen's-road, Swansea.
1873. ‡Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1887. ‡Steinthal, Rev. S. Alfred. 81 Nelson-street, Manchester.
1887. ‡Stelfox, John L. 6 Hilton-street, Oldham, Manchester.
1884. ‡Stephen, George. 140 Drummond-street, Montreal, Canada.
1884. ‡Stephen, Mrs. George. 140 Drummond-street, Montreal, Canada.
1884. *Stephens, W. Hudson. Lowville (P.O.), State of New York, U.S.A.
1879. *STEPHENSON, Sir HENRY, J.P. The Glen, Sheffield.
1870. **Stevens, Miss Anna Maria. 23 Elm Grove-terrace, London-road, Salisbury.*
1880. *Stevens, J. Edward, LL.B. 10 Cleveland-terrace, Swansea.
1886. ‡Stevens, Marshall. Highfield House, Urmston, near Manchester.
1892. ‡Stevenson, D. A., B.Sc., F.R.S.E., M.Inst.C.E. 84 George-street, Edinburgh.
1863. *STEVENSON, JAMES C., M.P., F.C.S. Westoe, South Shields.
1889. ‡*Stevenson, T. Shannon. Westoe, South Shields.*
1890. *Steward, Rev. Charles J., F.R.M.S. Somerleyton Rectory, Lowestoft.
1885. *Stewart, Rev. Alexander, M.D., LL.D. Heathcot, Aberdeen.
1887. *Stewart, A. H. St. Thomas's Hospital, London, S.E.
1892. ‡Stewart, C. Hunter. 3 Carlton-terrace, Edinburgh.
1864. ‡STEWART, CHARLES, M.A., F.L.S. St. Thomas's Hospital, London, S.E.
1885. ‡Stewart, David. Banchory House, Aberdeen.
1886. *Stewart, Duncan. 12 Montgomerie-crescent, Kelvinside, Glasgow.
1887. ‡Stewart, George N. Physiological Laboratory, Owens College, Manchester.
1875. *Stewart, James, B.A., F.R.C.P.Ed. Dunmurry, Sneyd Park, near Clifton, Gloucestershire.
1892. §Stewart, Samuel. Knocknairn, Bagston, Greenock.
1876. ‡Stewart, William. Violet Grove House, St. George's-road, Glasgow.
1867. ‡Stirling, Dr. D. Perth.
1876. ‡STIRLING, WILLIAM, M.D., D.Sc., F.R.S.E., Professor of Physiology in the Owens College, Manchester.
1867. *Stirrup, Mark, F.G.S. Stamford-road, Bowdon, Cheshire.
1865. *Stock, Joseph S. St. Mildred's, Walmer.
1890. ‡Stockdale, R. The Grammar School, Leeds.
1883. *STOCKER, W. N., M.A., Professor of Physics in the Royal Indian Engineering College. Cooper's Hill, Staines.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
1845. *STOKES, Sir GEORGE GABRIEL, Bart., M.A., D.C.L., LL.D., D.Sc., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Lensfield Cottage, Cambridge.
1887. ‡Stone, E. D., F.C.S. 19 Lever-street, Piccadilly, Manchester.

Year of Election.

1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.

1886. ‡Stone, J. B. The Grange, Erdington, Birmingham.

1886. ‡Stone, J. H. Grosvenor-road, Handsworth, Birmingham.

1874. ‡Stone, J. Harris, M.A., F.L.S., F.C.S. 3 Dr. Johnson's-buildings, Temple, London, E.C.

1888. ‡STONE, JOHN. 15 Royal-crescent, Bath.

1876. ‡Stone, Octavius C., F.R.G.S. 49 Bolsover-street, Regent's Park, London, N.W.

1883. ‡Stone, Thomas William. 189 Goldhawk-road, Shepherd's Bush, London, W.

1857. ‡STONEY, BINDON B., LL.D., F.R.S., M.Inst.C.E., M.R.I.A., Engineer of the Port of Dublin. 14 Elgin-road, Dublin.

1878. *Stoney, G. Gerald. 90 Meldon-terrace, Newcastle-upon-Tyne.

1861. *STONEY, GEORGE JOHNSTONE, M.A., D.Sc., F.R.S., M.R.I.A. 8 Upper Hornsey Rise, London, N.

1876. §Stopes, Henry, F.G.S. 31 Torrington-square, London, W.C.

1883. ‡Stopes, Mrs. 31 Torrington-square, London, W.C.

1887. ‡Storer, Edwin. Woodlands, Crumpsall, Manchester.

1887. *Storey, H. L. Caton, near Lancaster.

1873. §Storr, William. The 'Times' Office, Printing-house-square, London, E.C.

1884. §Storrs, George H. Fern Bank, Stalybridge.

1859. §Story, Captain James Hamilton. 17 Bryanston-square, London, W.

1888. *Stothert, Percy K. Audley, Park-gardens, Bath.

1874. ‡Stott, William. Scar Bottom, Greetland, near Halifax, Yorkshire.

1871. *STRACHEY, Lieut.-General RICHARD, R.E., C.S.I., LL.D., F.R.S., F.R.G.S., F.L.S., F.G.S. 69 Lancaster-gate, Hyde Park, London, W.

1881. ‡Strahan, Aubrey, M.A., F.G.S. Geological Museum, Jermyn-street, London, S.W.

1876. ‡Strain, John. 143 West Regent-street, Glasgow.

1863. ‡Straker, John. Wellington House, Durham.

1889. ‡Straker, Captain Joseph. Dilston House, Riding Mill-on-Tyne.

1882. ‡Strange, Rev. Cresswell, M.A. Edgbaston Vicarage, Birmingham.

1881. ‡Strangways, C. Fox, F.G.S. Geological Museum, Jermyn-street, London, S.W.

1889. §Streatfeild, H. S. The Limes, Leigham Court-road, Streatham, S.W.

*Strickland, Charles. 21 Fitzwilliam-place, Dublin.

1879. ‡Strickland, Sir Charles W., K.C.B. Hildenley-road, Malton.

1884. ‡Stringham, Irving. The University, Berkeley, California, U.S.A.

1859. ‡Stronach, William, R.E. Ardmellie, Banff.

1883. §Strong, Henry J., M.D. Colonnade House, The Steyne, Worthing.

1887. *Stroud, Professor H., M.A., D.Sc. College of Science, Newcastle-upon-Tyne.

1887. *STROUD, WILLIAM, D.Sc., Professor of Physics in the Yorkshire College, Leeds.

1876. *STRUTHERS, JOHN, M.D., LL.D., Emeritus Professor of Anatomy in the University of Aberdeen. 24 Buckingham-terrace, Edinburgh.

1878. ‡Strype, W. G. Wicklow.

1876. *Stuart, Charles Maddock. St. Dunstan's College, Catford, S.E.

1872. *Stuart, Rev. Edward A., M.A. 116 Grosvenor-road, Highbury New Park, London, N.

1886. ‡*Stuart, G. Morton, M.A. East Harptree, near Bristol.*

1892. ‡Stuart, Morton Gray, M.A. Ettrickbank, Selkirk.

Year of Election.

1884. ‡Stuart, Dr. W. Theophilus. 183 Spadina-avenue, Toronto, Canada.
1893. §Stubbs, Arthur G. Sherwood Rise, Nottingham.
1888. *Stubbs, Rev. Elias T., M.A. 4 Springfield-place, Bath.
1885. §Stump, Edward C. 16 Herbert-street, Moss Side, Manchester.
1879. *Styring, Robert. 3 Hartshead, Sheffield.
1891. *Sudborough, J. J., Ph.D., B.Sc. 9 Park-grove, Wordsworth-road, Birmingham.
1884. ‡Sumner, George. 107 Stanley-street, Montreal, Canada.
1887. ‡Sumpner, W. E. 37 Pennyfields, Poplar, London, E.
1888. ‡Sunderland, John E. Bark House, Hatherlow, Stockport.
1883. ‡Sutcliffe, J. S., J.P. Beech House, Bacup.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. Thurso House, Newcastle-upon-Tyne.
1886. ‡Sutherland, Hugh. Winnipeg, Manitoba, Canada.
1892. §Sutherland, James B. 10 Windsor-street, Edinburgh.
1884. ‡Sutherland, J. C. Richmond, Quebec, Canada.
1863. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1889. ‡Sutton, William. Esbank, Jesmond, Newcastle-upon-Tyne.
1891. ‡Swainson, George, F.L.S. North Drive, St. Anne's-on-Sea, Lancashire.
1881. ‡Swales, William. Ashville, Holgate Hill, York.
1876. ‡Swan, David, jun. Braeside, Maryhill, Glasgow.
1881. §Swan, Joseph Wilson, M.A. Lauriston, Bromley, Kent.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Emeritus Professor of Natural Philosophy in the University of St. Andrews. Ardchapel, Helensburgh, N.B.

*SWANSEA, The Right Hon. LORD, F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.

1879. ‡Swanwick, Frederick. Whittington, Chesterfield.
1883. ‡Sweeting, Rev. T. E. 50 Roe-lane, Southport.
1887. §SWINBURNE, JAMES. 4 Hatherley-road, Kew Gardens, London.
1870. *Swinburne, Sir John, Bart., M.P. Capheaton, Newcastle-upon-Tyne.
1885. ‡Swindells, Miss. Springfield House, Ilkley, Yorkshire.
1887. *Swindells, Rupert, F.R.G.S. Wilton Villa, The Firs, Bowdon, Cheshire.
1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1890. §SWINHOE, Colonel C. Avenue House, Oxford.
1891. §Swinnerton, R. W., Assoc.M.Inst.C.E. Bolarum, Dekkan, India.
1889. §Sworn, Sidney A., B.A., F.C.S. The Municipal Technical School, Gravesend.
1883. ‡Sykes, Alfred. Highfield, Huddersfield.
1873. ‡Sykes, Benjamin Clifford, M.D. St. John's House, Cleckheaton.
1887. *Sykes, George H., M.A., M.Inst.C.E., F.S.A. Glencoe, Elmbourne-road, Tooting Bec Common, London, S.W.
1890. ‡Sykes, Joseph. 113 Beeston-hill, Leeds.
1887. *Sykes, T. H. Cheadle, Cheshire.

SYLVESTER, JAMES JOSEPH, M.A., D.C.L., LL.D., F.R.S., Savilian Professor of Geometry in the University of Oxford.

1893. §Symes, Rev. J. E., M.A. 70 Redcliffe-crescent, Nottingham.
1870. ‡SYMES, RICHARD GLASCOTT, M.A., F.G.S., Geological Survey of Scotland. Sheriff Court-buildings, Edinburgh.
1885. ‡Symington, Johnson, M.D. 2 Greenhill Park, Edinburgh.
1881. *Symington, Thomas. Wardie House, Edinburgh.
1859. §SYMONS, G. J., F.R.S., Sec.R.Met.Soc. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. Dragon House, Bilbrook, near Taunton.

Year of Election.

1886. §Symons, W. H., F.I.C., F.R.M.S. 130 Fellowes-road, Hampstead, London, N.W.
1872. ‡*Synge, Major-General Millington, R.E., F.R.G.S. United Service Club, Pall Mall, London, S.W.*

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1877. *Tait, Lawson, F.R.C.S. The Crescent, Birmingham.
1871. ‡Tait, Peter Guthrie, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. George-square, Edinburgh.
1867. ‡Tait, P. M., F.S.S. 37 Charlotte-street, Portland-place, London, W.
1890. ‡Talbot, Rev. E. S. The Vicarage, Leeds.
1893. §Talbot, Herbert, M.I.E.E. 19 Addison-villas, Addison-street, Nottingham.
1891. ‡Tamblyn, James. Glan Llynvi, Maesteg, Bridgend.
1891. ‡Tanner, Colonel H. C. B. The Red House, Petersfield.
1890. ‡Tanner, H. W. Lloyd, M.A., Professor of Mathematics and Astronomy in University College, Cardiff.
1892. *Tansley, Arthur G. Trinity College, Cambridge.
1883. §Tapscott, R. L., F.G.S. 62 Croxteth-road, Liverpool.
1878. ‡Tarpey, Hugh. Dublin.
1861. *Tarratt, Henry W. Moseley, Owl's-road, Boscombe, Bournemouth.
1857. *Tate, Alexander. Longwood, Whitehouse, Belfast.
1893. §Tate, George, Ph.D., F.C.S. College of Chemistry, Duke-street, Liverpool.
1890. ‡Tate, Thomas, F.G.S. 5 Eldon-mount, Woodhouse-lane, Leeds.
1858. *Tatham, George, J.P. Springfield Mount, Leeds.
1886. ‡*Taunton, Richard. Brook Vale, Witton.*
1884. *Taylor, Rev. Charles, D.D. St. John's Lodge, Cambridge.
Taylor, Frederick. Laurel Cottage, Rainhill, near Prescot, Lancashire.
1887. §Taylor, G. H. Holly House, 235 Eccles New-road, Salford.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
1887. ‡Taylor, George Spratt, F.C.S. 13 Queen's-terrace, St. John's Wood, London, N.W.
1881. *Taylor, H. A. 25 Collingham-road, South Kensington, London, S.W.
1884. *Taylor, H. M., M.A. Trinity College, Cambridge.
1882. *Taylor, Herbert Owen, M.D. 17 Castlegate, Nottingham.
1887. ‡Taylor, Rev. Canon Isaac, D.D. Settrington Rectory, York.
1861. *Taylor, John, M.Inst.C.E., F.G.S. 29 Portman-square, London, W.
1873. ‡Taylor, John Ellor, Ph.D., F.L.S., F.G.S. The Mount, Ipswich.
1881. *Taylor, John Francis. Holly Bank House, York.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
1883. ‡Taylor, Michael W., M.D. Hatton Hall, Penrith.
1876. ‡Taylor, Robert. 70 Bath-street, Glasgow.
1884. *Taylor, Miss S. Oak House, Shaw, near Oldham.
1881. ‡Taylor, Rev. S. B., M.A. Whixley Hall, York.
1883. ‡Taylor, S. Leigh. Birklands, Westcliffe-road, Birkdale, Southport.
1870. ‡Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
1887. ‡Taylor, Tom. Grove House, Sale, Manchester.
1883. ‡Taylor, William, M.D. 21 Crockherbtown, Cardiff.
1893. §Taylor, W. F. Boswell Court, Croydon, Surrey.
1884. ‡Taylor-Whitehead, Samuel, J.P. Burton Closes, Bakewell.
1858. ‡Teale, Thomas Pridgin, M.A., F.R.S. 38 Cookridge-street, Leeds.

Year of Election.

1885. ‡TEALL, J. J. H., M.A., F.R.S., F.G.S. 28 Jermyn-street, London, S.W.
1879. ‡Temple, Lieutenant George T., R.N., F.R.G.S. The Nash, near Worcester.
1880. ‡TEMPLE, Sir RICHARD, Bart., G.C.S.I., C.I.E., D.C.L., LL.D., M.P., F.R.G.S. Athenæum Club, London, S.W.
1863. ‡Tennant, Henry. Saltwell, Newcastle-upon-Tyne.
1889. ‡Tennant, James. Saltwell, Gateshead.
1882. §Terrill, William. 42 St. George's-terrace, Swansea.
1881. ‡Terry, Sir Joseph. Hawthorn Villa, York.
1892. *Tesla, Nikola. 45 West 27th-street, New York, U.S.A.
1883. ‡Tetley, C. F. The Brewery, Leeds.
1883. ‡Tetley, Mrs. C. F. The Brewery, Leeds.
1887. ‡Tetlow, T. 273 Stamford-street, Ashton-under-Lyne.
1882. *Thane, George Dancer, Professor of Anatomy in University College, Gower-street, London, W.C.
1885. ‡Thin, Dr. George, 22 Queen Anne-street, London, W.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., C.M.G., C.I.E., M.A., B.Sc., Ph.D., F.R.S., F.L.S. Royal Gardens, Kew.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1891. ‡Thomas, Alfred, M.P. Pen-y-lan, Cardiff.
1871. ‡Thomas, Ascanius William Nevill. Chudleigh, Devon.
1891. ‡Thomas, A. Garrod, M.D., J.P. Clytha Park, Newport, Monmouthshire.
1891. *Thomas, Miss Clara. Llwynmadoc, Garth, R.S.O.
1891. ‡Thomas, Edward. 282 Bute-street, Cardiff.
1891. §Thomas, E. Franklin. Dan-y-Bryn, Radyr, near Cardiff.
1883. ‡*Thomas, Ernest C., B.A. 13 South-square, Gray's Inn, London, W.C.*
1875. *THOMAS, F. WOLFERSTAN. Molson's Bank, Montreal, Canada.
Thomas, George. Brislington, Bristol.
1875. ‡Thomas, Herbert. Ivor House, Redland, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1881. §THOMAS, J. BLOUNT. Southampton.
1892. ‡Thomas, J. C., B.Sc. Queen Elizabeth's Grammar School, Carmarthen.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1891. ‡Thomas, John Tubb, L.R.C.P. Eastfields, Newport, Monmouthshire.
1880. *Thomas, Joseph William, F.C.S. Drumpellier, Brunswick-road, Gloucester.
1883. ‡Thomas, P. Bossley. 4 Bold-street, Southport.
1883. §Thomas, Thomas H. 45 The Walk, Cardiff.
1883. ‡Thomas, William. Lan, Swansea.
1886. ‡Thomas, William. 109 Tettenhall-road, Wolverhampton.
1886. §Thomason, Yeoville. 9 Observatory-gardens, Kensington, London, W.
1875. ‡Thompson, Arthur. 12 St. Nicholas-street, Hereford.
1891. *Thompson, Beeby, F.C.S., F.G.S. 55 Victoria-road, Northampton.
1883. ‡Thompson, Miss C. E. Heald Bank, Bowdon, Manchester.
1891. ‡Thompson, Charles F. Penhill Close, near Cardiff.
1882. ‡Thompson, Charles O. Terre Haute, Indiana, U.S.A.
1888. *Thompson, Claude M., M.A., Professor of Chemistry in University College, Cardiff.

Year of
Election.

1885. ‡Thompson, D'Arcy W., B.A., Professor of Physiology in University College, Dundee. University College, Dundee.
1883. *Thompson, Francis. Lynton, Haling Park-road, Croydon.
1891. ‡Thompson, G. Carslake. Park-road, Penarth.
1859. ‡Thompson, George, jun. Pitmedden, Aberdeen.
1893. *Thompson, Harry J., M.Inst.C.E., Madras. Care of Messrs. Grindlay & Co., Parliament-street, London, S.W.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
1889. ‡*Thompson, Henry. 2 Eslington-terrace, Newcastle-upon-Tyne.*
1883. *Thompson, Henry G., M.D. 8 Addiscombe-villas, Croydon.
Thompson, Henry Stafford. Fairfield, near York.
1891. ‡Thompson, Herbert M. Whitley Batch, Llandaff.
1891. ‡Thompson, H. Wolcott. 9 Park-place, Cardiff.
1883. *THOMPSON, ISAAC COOKE, F.L.S., F.R.M.S. Woodstock, Waverley-road, Liverpool.
1891. ‡Thompson, J. Tatham. 23 Charles-street, Cardiff.
1861. *THOMPSON, JOSEPH. Riversdale, Wilmslow, Manchester.
1876. *Thompson, Richard. Dringcote, The Mount, York.
1883. ‡Thompson, Richard. Bramley Mead, Whalley, Lancashire.
1876. ‡THOMPSON, SILVANUS PHILLIPS, B.A., D.Sc., F.R.S., F.R.A.S., Professor of Physics in the City and Guilds of London Institute, Finsbury Technical Institute, E.C.
1883. *Thompson, T. H. Heald Bank, Bowdon, Manchester.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1889. *Thomson, James, M.A. 22 Wentworth-place, Newcastle-upon-Tyne.
1868. §THOMSON, JAMES, F.G.S. 22 Leven-street, Pollokshields, Glasgow.
1876. ‡Thomson, James R. Mount Blow, Dalmuir, Glasgow.
1891. ‡Thomson, John. 70A Grosvenor-street, London, W.
1890. §Thomson, J. Arthur, M.A., F.R.S.E., Lecturer on Zoology at the School of Medicine, Edinburgh. 30 Royal-circus, Edinburgh.
1883. ‡THOMSON, J. J., M.A., F.R.S., Professor of Experimental Physics in the University of Cambridge. Trinity College, Cambridge.
1871. *THOMSON, JOHN MILLAR, F.C.S., Professor of Chemistry in King's College, London. 53 Prince's-square, London, W.
1886. ‡Thomson, Joseph. Thornhill, Dumfriesshire.
1863. ‡Thomson, Murray. 44 Victoria-road, Gipsy Hill, London, S.E.
1874. §THOMSON, WILLIAM, F.R.S.E., F.C.S. Royal Institution, Manchester.
1880. §Thomson, William J. Ghyllbank, St. Helens.
1871. ‡Thornburn, Rev. David, M.A. 1 John's-place, Leith.
1886. §Thornley, J. E. Lyndon, Bickenhill, near Birmingham.
1887. ‡Thornton, John. 3 Park-street, Bolton.
1867. ‡Thornton, Thomas. Dundee.
1883. §Thorowgood, Samuel. Castle-square, Brighton.
1845. ‡Thorp, Dr. Disney. Lypiatt Lodge, Suffolk Lawn, Cheltenham.
1881. ‡Thorp, Fielden. Blossom-street, York.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
1881. *Thorp, Josiah. 87 Selborne-street, Liverpool.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 24 Crouch Hall-road, Crouch End, London, N.
1871. ‡THORPE, T. E., Ph.D., F.R.S., F.R.S.E., F.C.S., Professor of Chemistry in the Royal College of Science, South Kensington, London, S.W.
1883. §Threlfall, Henry Singleton. 12 London-street, Southport.
1883. ‡*Thresh, John C., D.Sc. The Willows, Buxton.*

Year of Election.

1868. ‡THUILLIER, General Sir H. E. L., R.A., C.S.I., F.R.S., F.R.G.S. Tudor House, Richmond Green, Surrey.

1889. ‡Thys, Captain Albert. 9 Rue Briderode, Brussels.

1870. ‡Tichborne, Charles R. C., LL.D., F.C.S., M.R.I.A. Apothecaries' Hall of Ireland, Dublin.

1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.

1874. ‡TILDEN, WILLIAM A., D.Sc., F.R.S., F.C.S., Professor of Chemistry and Metallurgy in the Mason Science College, Birmingham.

1873. ‡Tilghman, B. C. Philadelphia, U.S.A.

1883. ‡Tillyard, A. I., M.A. Fordfield, Cambridge.

1883. ‡Tillyard, Mrs. Fordfield, Cambridge.

1865. ‡Timmins, Samuel, J.P., F.S.A. Hill Cottage, Fillongley, Coventry.

1876. ‡Todd, Rev. Dr. Tudor Hall, Forest Hill, London, S.E.

1891. §Todd, Richard Rees. Portuguese Consulate, Cardiff.

1889. §Toll, John M. Carlton House, Kirkby, near Liverpool.

1887. ‡*Tolmé, Mrs. Melrose House, Higher Broughton, Manchester.*

1857. ‡Tombe, Rev. Canon. Glenealy, Co. Wicklow.

1888. ‡Tomkins, Rev. Henry George. Park Lodge, Weston-super-Mare.

1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 7 North-road, Highgate, London, N.

1887. ‡Tonge, Rev. Canon. Chorlton-cum-Hardy, Manchester.

1887. ‡Tonge, James. Woodbine House, West Houghton, Bolton.

1865. ‡Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.

1865. *Tonks, William Henry. The Rookery, Sutton Coldfield.

1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.

1887. ‡Topham, F. 15 Great George-street, London, S.W.

1861. *Topham, John, A.I.C.E. 53 Annandale-road, Vanbrugh Hill, London, S.E.

1872. *TOPLEY, WILLIAM, F.R.S., F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.

1886. ‡Topley, Mrs. W. 13 Havelock-road, Croydon.

1875. ‡Torr, Charles Hawley. St. Alban's Tower, Mansfield-road, Sherwood, Nottingham.

1886. ‡Torr, Charles Walker. Cambridge-street Works, Birmingham.

1884. ‡Torrance, John F. Folly Lake, Nova Scotia, Canada.

1884. *Torrance, Rev. Robert, D.D. Guelph, Ontario, Canada.

Towgood, Edward. St. Neot's, Huntingdonshire.

1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.

1875. ‡Townsend, Charles. St. Mary's, Stoke Bishop, Bristol.

1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.

1877. ‡Tozer, Henry. Ashburton.

1876. *TRAIL, J. W. H., M.A., M.D., F.R.S., F.L.S., Regius Professor of Botany in the University of Aberdeen.

1883. ‡TRAILL, A., M.D., LL.D. Ballylough, Bushmills, Ireland.

1870. ‡TRAILL, WILLIAM A. Giant's Causeway Electric Tramway, Portrush, Ireland.

1875. ‡*Trapnell, Caleb. Severnleigh, Stoke Bishop.*

1868. ‡TRAQUAIR, RAMSAY H., M.D., LL.D., F.R.S., F.G.S., Keeper of the Natural History Collections, Museum of Science and Art, Edinburgh.

1891. ‡Trayes, Valentine. The Hill, Abergavenny.

1884. ‡Trechmann, Charles O., Ph.D., F.G.S. Hartlepool.

1868. ‡Trehane, John. Exe View Lawn, Exeter.

1891. ‡Treharne, J. Ll. 92 Newport-road, Cardiff.

Trench, F. A. Newlands House, Clondalkin, Ireland.

Year of Election.

1887. *Trench-Gascoigne, Mrs. F. R. Parlington, Aberford, Leeds.
1883. ‡Trendell, Edwin James, J.P. Abbey House, Abingdon, Berks.
1884. ‡Trenham, Norman W. 18 St. Alexis-street, Montreal, Canada.
1884. §Tribe, Paul C. M. 44 West Oneida-street, Oswego, New York, U.S.A.
1879. ‡Trickett, F. W. 12 Old Haymarket, Sheffield.
1877. ‡Trimen, Henry, M.B., F.R.S., F.L.S. Peradeniya, Ceylon.
1871. ‡Trimen, Roland, F.R.S., F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §Tristram, Rev. Henry Baker, D.D., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1884. *Trotter, Alexander Pelham. 22 Cottesmore-gardens, Victoria-road, Kensington, London, W.
1885. §Trotter, Coutts, F.G.S., F.R.G.S. 17 Charlotte-square, Edinburgh.
1891. ‡Trounce, W. J. 67 Newport-road, Cardiff.
1887. *Trouton, Frederick T., M.A., D.Sc. Trinity College, Dublin.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1885. *Tubby, A. H. Guy's Hospital, London, S.E.
1847. *Tuckett, Francis Fox. Frenchay, Bristol.
1888. ‡Tuckett, William Fothergill, M.D. 18 Daniel-street, Bath.
Tuke, James H. Bancroft, Hitchin.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1887. ‡Tuke, W. C. 29 Princess-street, Manchester.
1883. ‡Tupper, The Hon. Sir Charles, Bart., G.C.M.G., C.B., High Commissioner for Canada. 9 Victoria-chambers, London, S.W.
1892. §Turnbull, Alexander R. Ormiston House, Hawick.
1855. ‡Turnbull, John. 37 West George-street, Glasgow.
1893. §Turner, Dawson, M.B. 37 George-square, Edinburgh.
1891. ‡Turner, Miss E. R. Ipswich.
1882. ‡*Turner, G. S. 9 Carlton-crescent, Southampton.*
1883. ‡*Turner, Mrs. G. S. 9 Carlton-crescent, Southampton.*
1888. ‡Turner, J. S., J.P. Granville, Lansdowne, Bath.
1886. *Turner, Thomas, A.R.S.M., F.C.S., F.I.C. Mason Science College, Birmingham.
1863. *Turner, Sir William, M.B., LL.D., D.C.L., F.R.S., F.R.S.E., Professor of Anatomy in the University of Edinburgh. 6 Eton-terrace, Edinburgh.
1893. §Turney, Sir John, J.P. Alexandra Park, Nottingham.
1890. *Turpin, G. S., M.A., D.Sc. 2 St. James's-terrace, Nottingham.
1885. ‡Turrell, Miss S. S. High School, Redland-grove, Bristol.
1884. *Tutin, Thomas. The Orchard, Chellaston, Derby.
1884. *Tweddell, Ralph Hart. Meopham Court, Gravesend, Kent.
1886. *Twigg, G. H. Church-road, Moseley, Birmingham.
1847. ‡Twiss, Sir Travers, Q.C., D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1888. §Tyack, Llewellyn Newton. University College, Bristol.
1882. §Tyer, Edward. Horneck, Fitzjohn's-avenue, Hampstead, London, N.W.
1865. §Tylor, Edward Burnett, D.C.L., LL.D., F.R.S., Keeper of the University Museum, Oxford.
1883. ‡Tyrer, Thomas, F.C.S. Garden-wharf, Battersea, London, S.W.
1861. *Tysoe, John. 28 Heald-road, Bowdon, near Manchester.

1884. *Underhill, G. E., M.A. Magdalen College, Oxford.
1888. ‡Underhill, H. M. 7 High-street, Oxford.

Year of Election.

1886. ‡Underhill, Thomas, M.D. West Bromwich.
1885. §Unwin, Howard. Newton-grove, Bedford Park, Chiswick, London.
1883. §Unwin, John. Park-crescent, Southport.
1883. §Unwin, William Andrews. The Briars, Freshfield, near Liverpool.
1876. *UNWIN, W. C., F.R.S., M.Inst.C.E., Professor of Engineering at the Central Institution of the City and Guilds of London Institute. 7 Palace-gate Mansions, Kensington, London, W.
1887. ‡Upton, Francis R. Orange, New Jersey, U.S.A.
1872. ‡Upward, Alfred. 150 Holland-road, London, W.
1876. ‡Ure, John F. 6 Claremont-terrace, Glasgow.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. ‡Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1880. ‡USSHER, W. A. E., F.G.S. 28 Jermyn-street, London, S.W.

1885. ‡Vachell, Charles Tanfield, M.D. 38 Charles-street, Cardiff.
1887. *Valentine, Miss Anne. The Elms, Hale, near Altrincham.
1888. ‡Vallentin, Rupert. 18 Kimberley-road, Falmouth.
1884. ‡Van Horne, W. C. Dorchester-street West, Montreal, Canada.
1883. *Vansittart, The Hon. Mrs. A. A. Haywood House, Oaklands-road, Bromley, Kent.
1886. ‡VARDY, Rev. A. R., M.A. King Edward's School, Birmingham.
1868. ‡Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay-avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. 5 Gayton-road, Hampstead, London, N.W.
1870. ‡Varley, Mrs. S. A. 5 Gayton-road, Hampstead, London, N.W.
1869. ‡Varwell, P. Alphington-street, Exeter.
1884. ‡Vasey, Charles. 112 Cambridge-gardens, London, W.
1887. *VAUGHAN, His Eminence Cardinal. Archbishop's House, Carlisle-place, Westminster, S.W.
1875. ‡Vaughan, Miss. Burlton Hall, Shrewsbury.
1883. ‡Vaughan, William. 42 Sussex-road, Southport.
1881. §VELEY, V. H., M.A., F.C.S. 22 Norham-road, Oxford.
1873. *VERNEY, Captain EDMUND H., R.N., F.R.G.S. Claydon House, Winslow, Bucks.
1883. *Verney, Mrs. Claydon House, Winslow, Bucks.
Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1883. ‡VERNON, H. H., M.D. York-road, Birkdale, Southport.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-crescent, Exeter.
1890. *Villamil, Major R. de, R.E. Care of Messrs. Cox & Co., 16 Charing Cross, London, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1883. *Vines, Sydney Howard, M.A., D.Sc., F.R.S., F.L.S., Professor of Botany in the University of Oxford. Headington Hill, Oxford.
1891. ‡Vivian Stephen. Llantrisant.

1886. *Wackrill, Samuel Thomas, J.P. Leamington.
1860. ‡Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1890. ‡Wadsworth, George Henry. 3 Southfield-square, Bradford, Yorkshire.
1888. ‡Wadworth, H. A. Breinton Court, near Hereford.
1890. §WAGER, HAROLD W. T. Yorkshire College, Leeds.
1891. ‡Wailes, T. W. 23 Richmond-road, Cardiff.
1884. ‡Wait, Charles E., Professor of Chemistry in the University of Tennessee. Knoxville, Tennessee, U.S.A.

Year of
Election.
1886. ‡Waite, J. W. The Cedars, Bestcot, Walsall.
1870. ‡WAKE, CHARLES STANILAND. Welton, near Brough, East Yorkshire.
1892. ‡Walcot, John. 50 Northumberland-street, Edinburgh.
1884. ‡Waldstein, Charles, M.A., Ph.D. Cambridge.
1891. ‡Wales, H. T. Pontypridd.
1873. ‡*Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.*
1891. ‡Walford, Edward, M.D. Thanet House, Cathedral-road, Cardiff.
1882. *Walkden, Samuel. 3 West End-terrace, Winchester.
1893. §Walker, Alfred O., F.L.S. Nant-y-Glyn, Colwyn Bay.
1890. ‡Walker, A. Tannett. Hunslet, Leeds.
1885. ‡Walker, Mr. Baillie. 52 Victoria-street, Aberdeen.
1885. ‡Walker, Charles Clement, F.R.A.S. Lillieshall Old Hall, Newport, Shropshire.
1883. §Walker, Mrs. Emma. 18 Lendal, York.
1883. ‡Walker, E. R. Pagefield Ironworks, Wigan.
Walker, Frederick John. The Priory, Bathwick, Bath.
1891. ‡Walker, Frederick W. Hunslet, Leeds.
1883. ‡Walker, George. 11 Hamilton-square, Birkenhead, Liverpool.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1890. ‡Walker, Dr. James. 8 Windsor-terrace, Dundee.
1885. ‡WALKER, General J. T., C.B., R.E., LL.D., F.R.S., F.R.G.S. 13 Cromwell-road, London, S.W.
1866. *WALKER, JOHN FRANCIS, M.A., F.C.S., F.G.S., F.L.S. 45 Bootham, York.
1855. ‡WALKER, JOHN JAMES, M.A., F.R.S. 12 Denning-road, Hampstead, London, N.W.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1886. *Walker, Major Philip Billingsley. Sydney, New South Wales.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1884. ‡Walker, Samuel. Woodbury, Sydenham Hill, London, S.E.
1888. ‡Walker, Sydney F. 195 Severn-road, Cardiff.
1887. ‡Walker, T. A. 15 Great George-street, London, S.W.
1883. ‡Walker, Thomas A. 66 Leyland-road, Southport.
Walker, William. 47 Northumberland-street, Edinburgh.
1881. *Walker, William. 18 Lendall, York.
1883. ‡Wall, Henry. 14 Park-road, Southport.
1863. ‡WALLACE, ALFRED RUSSEL, D.C.L., F.R.S., F.L.S., F.R.G.S. Corfe View, Parkstone, Dorset.
1892. §Wallace, Robert W. 14 Frederick-street, Edinburgh.
1887. *Waller, Augustus, M.D., F.R.S. Weston Lodge, 16 Grove End-road, London, N.W.
1889. *Wallis, Arnold J., M.A. 5 Belvoir-terrace, Cambridge.
1883. ‡Wallis, Rev. Frederick. Caius College, Cambridge.
1884. ‡Wallis, Herbert. Redpath-street, Montreal, Canada.
1886. ‡Wallis, Whitworth, F.S.A. Westfield, Westfield-road, Edgbaston, Birmingham.
1883. ‡Walmesley, Oswald. Shevington Hall, near Wigan.
1887. ‡Walmsley, J. Monton Lodge, Eccles, Manchester.
1891. §Walmsley, Professor R. M., D.Sc. Heriot Watt College, Edinburgh.
1883. ‡Walmsley, T. M. Clevelands, Chorley-road, Heaton, Bolton.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., F.R.S. Ealing, Middlesex, W.
1881. ‡Walton, Thomas, M.A. Oliver's Mount School, Scarborough.
1863. ‡Wanklyn, James Alfred. 7 Westminster-chambers, London, S.W.
1884. ‡Wanless, John, M.D. 88 Union-avenue, Montreal, Canada.
1887. ‡Ward, A. W., M.A., Litt.D., Principal of Owens College, Manchester.

Year of Election.

1874. §Ward, F. D., J.P., M.R.I.A. Clonaver, Strandtown, Co. Down.
1881. §Ward, George, F.C.S. Buckingham-terrace, Headingley, Leeds.
1879. ‡WARD, H. MARSHALL, M.A., F.R.S., F.L.S., Professor of Botany in the Royal Indian Civil Engineering College, Cooper's Hill, Egham.
1890. ‡Ward, Alderman John. Moor Allerton House, Leeds.
1874. §Ward, John, F.S.A. Lenoxvale, Belfast.
1887. §WARD, JOHN, F.G.S. 23 Stafford-street, Longton, Staffordshire.
1857. ‡Ward, John S. Prospect Hill, Lisburn, Ireland.
1880. *Ward, J. Wesney. Red House, Ravensbourne Park, Catford, S.E.
1884. *Ward, John William. Newstead, Halifax.
1883. ‡Ward, Thomas, F.C.S. Arnold House, Blackpool.
1887. ‡Ward, Thomas. Brookfield House, Northwich.
1882. ‡Ward, William. Cleveland Cottage, Hill-lane, Southampton.
1867. ‡Warden, Alexander J. 23 Panmure-street, Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1884. §Wardwell, George J. Rutland, Vermont, U.S.A.
1887. *Waring, Richard S. Pittsburg, Pennsylvania, U.S.A.
1878. §WARINGTON, ROBERT, F.R.S., F.C.S. Harpenden, St. Albans, Herts.
1882. ‡Warner, F. I., F.L.S. 20 Hyde-street, Winchester.
1884. *Warner, James D. 199 Baltic-street, Brooklyn, U.S.A.
1875. ‡Warren, Algernon. 6 Windsor-terrace, Clifton, Bristol.
1887. ‡WARREN, Major-General Sir CHARLES, R.E., K.C.B., G.C.M.G., F.R.S., F.R.G.S. Athenæum Club, London, S.W.
1893. §Warwick, W. D. Balderton House, Newark-on-Trent.
1875. *Waterhouse, Lieut.-Colonel J. 40 Hamilton-terrace, London, N.W.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1892. ‡Waterston, James H. 37 Lutton-place, Edinburgh.
1875. ‡Watherston, Rev. Alexander Law, M.A., F.R.A.S. The Grammar School, Hinckley, Leicestershire.
1881. §Watherston, E. J. 12 Pall Mall East, London, S.W.
1887. ‡Watkin, F. W. 46 Auriol-road, West Kensington, London, W.
1884. ‡Watson, A. G., D.C.L. Uplands, Wadhurst, Sussex.
1886. *Watson, C. J. Alton Cottage, Bottville-road, Acock's Green, Birmingham.
1883. ‡Watson, C. Knight, M.A. Society of Antiquaries, Burlington House, London, W.
1892. §Watson, G. 9 Victoria-chambers, South Parade, Leeds.
1885. ‡Watson, Deputy Surgeon-General G. A. Hendre, Overton Park, Cheltenham.
1882. ‡WATSON, Rev. H. W., D.Sc., F.R.S. Berkeswell Rectory, Coventry.
1887. ‡Watson, J. Beauchamp. Gilt Hall, Carlisle.
1884. ‡Watson, John. Queen's University, Kingston, Ontario, Canada.
1889. ‡Watson, John, F.I.C. 19 Bloomfield-terrace, Gateshead.
1863. ‡Watson, Joseph. Bensham-grove, Gateshead.
1863. ‡Watson, R. Spence, LL.D., F.R.G.S. Bensham-grove, Gateshead.
1867. ‡Watson, Thomas Donald. 23 Cross-street, Finsbury, London, E.C.
1892. §Watson, William, M.D. Slateford, Midlothian.
1879. *WATSON, WILLIAM HENRY, F.C.S., F.G.S. Braystones, Cumberland.
1882. ‡Watt, Alexander. 89 Hartington-road, Sefton Park, Liverpool.
1884. ‡Watt, D. A. P. 284 Upper Stanley-street, Montreal, Canada.
1869. ‡Watt, Robert B. E., F.R.G.S. Ashley-avenue, Belfast.
1888. ‡WATTS, B. H. 10 Rivers-street, Bath.

Year of Election.

1891. *Watts, E. Hannay, F.R.G.S. Springfield, Newport, Monmouthshire.
1875. *WATTS, JOHN, B.A., D.Sc. Merton College, Oxford.
1884. *Watts, Rev. Robert R. Stourpaine Vicarage, Blandford.
1870. §Watts, William, F.G.S. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1883. §Watts, W. W., M.A., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and Corndon, Worcester-road, Sutton, Surrey.
1891. ‡Waugh, James. Higher Grade School, 110 Newport-road, Cardiff.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1883. ‡Webb, George. 5 Tenterden-street, Bury, Lancashire.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
1890. ‡Webb, Sidney. 4 Park-village East, London, N.W.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1886. §WEBBER, Major-General C. E., C.B., M.Inst.C.E. 17 Egerton-gardens, London, S.W.
1891. §Webber, Thomas. Kensington Villa, 6 Salisbury-road, Cardiff.
1859. ‡Webster, John. Edgehill, Aberdeen.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1882. *Webster, Sir Richard Everard, LL.D., Q.C., M.P. Hornton Lodge, Hornton-street, Kensington, London, S.W.
1889. *Webster, William, F.C.S. 50 Lee Park, Lee, Kent.
1884. *Wedekind, Dr. Ludwig, Professor of Mathematics at Karlsruhe. Karlsruhe.
1889. ‡Weeks, John G. Bedlington.
1890. §Weiss, F. Ernest, B.Sc., F.L.S., Professor of Botany in Owens College, Manchester.
1886. ‡Weiss, Henry. Westbourne-road, Birmingham.
1865. ‡Welch, Christopher, M.A. United University Club, Pall Mall East, London, S.W.
1876. *WELDON, W. F. R., M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. 30A Wimpole-street, London, W.
1880. *Weldon, Mrs. 30A Wimpole-street, London, W.
1881. §Wellcome, Henry S. First Avenue Hotel, Holborn, London, W.C.
1879. §WELLS, CHARLES A., A.I.E.E. 219 High-street, Lewes.
1881. §Wells, Rev. Edward, B.A. Denton Rectory, Canterbury.
1883. ‡Welsh, Miss. Girton College, Cambridge.
1887. *Welton, T. A. Rectory House-grove, Clapham, London, S.W.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
1881. *Wenlock, The Right Hon. Lord. 8 Great Cumberland-place, London, W.; and Escrick Park, Yorkshire.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Hensingham, Whitehaven, Cumberland.
1886. §Wertheimer, J., B.A., B.Sc., F.C.S. Merchant Venturers' School, Bristol.
1865. ‡Wesley, William Henry. Royal Astronomical Society, Burlington House, London, W.
1853. ‡West, Alfred. Holderness-road, Hull.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡*West, Stephen. Hessle Grange, near Hull.*

Year of Election.

1882. *Westlake, Ernest, F.G.S. 2 Ridgeway-road, Redhill.
1882. ‡Westlake, Richard. Portswood, Southampton.
1875. *Weston, Sir Joseph D., M.P. Dorset House, Clifton Down Bristol.
1882. ‡WETHERED, EDWARD, F.G.S. 4 St. Margaret's-terrace, Cheltenham.
1884. ‡Wharton, E. R., M.A. 4 Broad-street, Oxford.
1885. *WHARTON, Captain W. J. L., R.N., F.R.S., F.R.A.S., F.R.G.S., Hydrographer to the Admiralty. Florys, Prince's-road, Wimbledon Park, Surrey.
1888. ‡Wheatcroft, William G. 6 Widcombe-terrace, Bath.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1884. ‡Wheeler, Claude L., M.D. 251 West 52nd-street, New York City, U.S.A.
1883. *Wheeler, George Brash. Elm Lodge, Wickham-road, Beckenham, Kent.
1878. *Wheeler, W. H., M.Inst.C.E. Boston, Lincolnshire.
1888. §Whelen, John Leman. Bank House, 16 Old Broad-street, London, E.C.
1883. ‡Whelpton, Miss K. Newnham College, Cambridge.
1893. *WHETHAM, W. C. D., M.A. Trinity College, Cambridge.
1888. *Whidborne, Miss Alice Maria. Charanté, Torquay.
1888. *Whidborne, Miss Constance Mary. Charanté, Torquay.
1879. *WHIDBORNE, Rev. GEORGE FERRIS, M.A., F.G.S. St. George's Vicarage, Battersea Park-road, London, S.W.
1874. ‡*Whitaker, Henry, M.D. 33 High-street, Belfast.*
1883. *Whitaker, T. Savile Heath, Halifax.
1859. *WHITAKER, WILLIAM, B.A., F.R.S., F.G.S. Geological Survey Office, Jermyn-street, London, S.W.; and 33 East Park-terrace, Southampton.
1884. ‡Whitcher, Arthur Henry. Dominion Lands Office, Winnipeg, Canada.
1886. ‡Whitcombe, E. B. Borough Asylum, Winson Green, Birmingham.
1886. ‡White, Alderman, J.P. Sir Harry's-road, Edgbaston, Birmingham.
1876. ‡White, Angus. Easdale, Argyllshire.
1886. ‡White, A. Silva. 47 Clanricarde-gardens, London, W.
1883. ‡White, Charles. 23 Alexandra-road, Southport.
1882. ‡White, Rev. George Cecil, M.A. Nutshalling Rectory, Southampton.
1885. *White, J. Martin. Balruddery, near Dundee.
1873. ‡White, John. Medina Docks, Cowes, Isle of Wight.
1859. ‡WHITE, JOHN FORBES. 311 Union-street, Aberdeen.
1883. ‡White, John Reed. Rossall School, near Fleetwood.
1865. ‡White, Joseph. Regent-street, Nottingham.
1884. ‡White, R. 'Gazette' Office, Montreal, Canada.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1877. *White, William. 9 The Paragon, Blackheath, London, S.E.
1883. *White, Mrs. 9 The Paragon, Blackheath, London, S.E.
1886. *White, William. The Ruskin Museum, Sheffield.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. **Whitehead, Peter Ormerod. 99 New John-street West, Birmingham.*
1883. ‡Whitehead, P. J. 6 Cross-street, Southport.
1871. ‡*Whitelaw, Alexander. 1 Oakley-terrace, Glasgow.*
1884. ‡*Whiteley, Joseph. Huddersfield.*

Year of Election.

1893. §Whiteley, R. Lloyd, F.C.S., F.I.C. 13 Bowers'-avenue, Nottingham.
1881. ‡Whitfield, John, F.C.S. 113 Westborough, Scarborough.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Canon C. T., M.A., F.R.A.S. Bedlington Vicarage, Northumberland.
1891. §Whitmell, Charles Thomas, M.A., B.Sc., F.G.S. 47 Park-place, Cardiff.
1857. *Whitty, Rev. John Irwine, M.A., D.C.L., LL.D. 1 Rodbourne-villas, Crescent-road, Ramsgate.
1887. ‡Whitwell, William. Overdene, Saltburn-by-the-Sea.
1874. *Whitwill, Mark. Redland House, Bristol.
1883. ‡Whitworth, James. 88 Portland-street, Southport.
1870. ‡Whitworth, Rev. W. Allen, M.A. 7 Margaret-street, London, W.
1892. §Whyte, Peter, M.Inst.C.E. 3 Clifton-terrace, Edinburgh.
1888. ‡Wickham, Rev. F. D. C. Horsington Rectory, Bath.
1865. ‡Wiggin, Sir Henry, Bart. Metchley Grange, Harborne, Birmingham.
1886. ‡Wiggin, Henry A. The Lea, Harborne, Birmingham.
1885. ‡Wigglesworth, Alfred. Gordondale House, Aberdeen.
1883. ‡Wigglesworth, Mrs. Ingleside, West-street, Scarborough.
1881. *Wigglesworth, Robert. Beckwith Knowle, near Harrogate.
1878. ‡Wigham, John R. Albany House, Monkstown, Dublin.
1883. ‡Wigner, G. W. Plough-court, 37 Lombard-street, London, E.C.
1889. *Wilberforce, L. R., M.A. Trinity College, Cambridge.
1881. ‡Wilberforce, W. W. Fishergate, York.
1887. ‡Wild, George. Bardsley Colliery, Ashton-under-Lyne.
1887. *Wilde, Henry, F.R.S. The Hurst, Alderley Edge, Manchester.
1887. ‡Wilkinson, C. H. Slaithwaite, near Huddersfield.
1857. ‡Wilkinson, George. Temple Hill, Killiney, Co. Dublin.
1892. §Wilkinson, Rev. J. Frome. Kivington Rectory, Orston, Nottingham.
1886. *Wilkinson, J. H. Corporation-street, Birmingham.
1879. ‡Wilkinson, Joseph. York.
1887. *Wilkinson, Thomas Read. The Polygon, Ardwick, Manchester.
1872. ‡Wilkinson, William. 168 North-street, Brighton.
1890. ‡Willans, J. W. Kirkstall, Leeds.
1859. ‡Willet, John, M.Inst.C.E. 35 Albyn-place, Aberdeen.
1872. ‡Willett, Henry, F.G.S. Arnold House, Brighton.
1893. §Williams, Arthur. 5 Thurland-street, Nottingham.
1891. ‡Williams, Arthur J., M.P. Coedymwstwr, near Bridgend.
1861. *Williams, Charles Theodore, M.A., M.B. 2 Upper Brook-street, Grosvenor-square, London, W.
1887. ‡Williams, E. Leader, M.Inst.C.E. The Oaks, Altrincham.
1883. *Williams, Edward Starbuck. Ty-ar-y-graig, Swansea.
1861. *Williams, Harry Samuel, M.A., F.R.A.S. 6 Heathfield, Swansea.
1875. *Williams, Rev. Herbert Addams. Llangibby Rectory, near Newport, Monmouthshire.
1883. ‡Williams, Rev. H. A. The Ridgeway, Wimbledon, Surrey.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1888. ‡Williams, James. Bladud Villa, Entryhill, Bath.
1891. §Williams, J. A. B., M.Inst.C.E. The Cedars, Llandaff-road, Cardiff.
1887. ‡Williams, J. Francis, Ph.D. Salem, New York, U.S.A.
1888. *Williams, Miss Katherine. Llandaff House, Pembroke-vale, Clifton, Bristol.
1875. *Williams, M. B. Killay House, near Swansea.
1879. ‡Williams, Matthew W., F.C.S. 26 Elizabeth-street, Liverpool.
1891. ‡Williams, Morgan. 5 Park-place, Cardiff.

Year of
Election.

1886. ‡Williams, Richard, J.P. Brunswick House, Wednesbury.
1883. ‡Williams, R. Price. North Brow, Primrose Hill, London, N.W.
1883. ‡Williams, T. H. 2 Chapel-walk, South Castle-street, Liverpool.
1888. ‡Williams, W. Cloud House, Stapleford, Nottinghamshire.
1877. *WILLIAMS, W. CARLETON, F.C.S. Firth College, Sheffield.
1883. ‡Williamson, Miss. Sunnybank, Ripon, Yorkshire.
1850. *WILLIAMSON, ALEXANDER WILLIAM, Ph.D., LL.D., D.C.L., F.R.S., F.C.S., Corresponding Member of the French Academy. High Pitfold, Haslemere.
1857. ‡WILLIAMSON, BENJAMIN, M.A., D.C.L., F.R.S. Trinity College, Dublin.
1876. ‡Williamson, Rev. F. J. Ballantrae, Girvan, N.B.
1863. ‡Williamson, John. South Shields.
WILLIAMSON, WILLIAM C., LL.D., F.R.S., Emeritus Professor of Botany in Owens College, Manchester. 43 Elms-road, Clapham Common, London, S.W.
1882. ‡Willmore, Charles. Queenwood College, near Stockbridge, Hants.
1859. *Wills, The Hon. Sir Alfred. Chelsea Lodge, Tite-street, London, S.W.
1886. ‡Wills, A. W. Wylde Green, Erdington, Birmingham.
1886. ‡Wilson, Alexander B. Holywood, Belfast.
1885. ‡Wilson, Alexander H. 2 Albyn-place, Aberdeen.
1878. ‡Wilson, Professor Alexander S., M.A., B.Sc. Free Church Manse, North Queensferry.
1876. ‡Wilson, Dr. Andrew. 118 Gilmore-place, Edinburgh.
1894. *Wilson, Charles J., F.I.C., F.C.S. 19 Little Queen-street, Westminster, S.W.
1874. ‡WILSON, Colonel Sir C. W., R.E., K.C.B., K.C.M.G., D.C.L., F.R.S., F.R.G.S. Ordnance Survey Office, Southampton.
1876. ‡Wilson, David. 124 Bothwell-street, Glasgow.
1890. ‡Wilson, Edmund. Denison Hall, Leeds.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 73 Newman-street, Oxford-street, London, W.
1875. ‡Wilson, George Fergusson, F.R.S., F.C.S., F.L.S. Heatherbank, Weybridge Heath, Surrey.
1874. *Wilson, George Orr. Dunardagh, Blackrock, Co. Dublin.
1863. ‡Wilson, George W. Heron Hill, Hawick, N.B.
1883. *Wilson, Henry, M.A. Farnborough Lodge R.S.O., Kent.
1879. ‡Wilson, Henry J. 255 Pitsmoor-road, Sheffield.
1885. ‡Wilson, J. Dove, LL.D. 17 Rubislaw-terrace, Aberdeen.
1886. ‡Wilson, J. E. B. Woodslee, Wimbledon, Surrey.
1890. ‡Wilson, J. Mitchell, M.D. 51 Hall Gate, Doncaster.
1865. ‡WILSON, Rev. JAMES M., M.A., F.G.S. The Vicarage, Rochdale.
1884. ‡Wilson, James S. Grant. Geological Survey Office, Sheriff Court-buildings, Edinburgh.
1879. ‡Wilson, John Wycliffe. Eastbourne, East Bank-road, Sheffield.
1876. ‡Wilson, R. W. R. St. Stephen's Club, Westminster, S.W.
1847. *Wilson, Rev. Sumner. Preston Candover Vicarage, Basingstoke.
1883. ‡Wilson, T. Rivers Lodge, Harpenden, Hertfordshire.
1892. §Wilson, T. Stacey, M.D. Wyddrington, Edgbaston, Birmingham.
1861. ‡Wilson, Thos. Bright. 4 Hope View, Fallowfield, Manchester.
1887. §Wilson, W., jun. Hillock, Terpersie, by Alford, Aberdeenshire.
1871. *Wilson, William E. Daramona House, Rathowen, Ireland.
1861. *WILTSHIRE, Rev. THOMAS, M.A., F.G.S., F.L.S., F.R.A.S., Professor of Geology and Mineralogy in King's College, London. 25 Granville-park, Lewisham, London, S.E.

Year of Election.

1877. ‡Windeatt, T. W. Dart View, Totnes.
1886. §WINDLE, BERTRAM C. A., M.A., M.D., D.Sc., Professor of Anatomy in Mason College, Birmingham.
1887. ‡Windsor, William Tessimond. Sandiway, Ashton-on-Mersey.
1893. *Winter, G. K., M.Inst.C.E., F.R.A.S. Arkonam, Madras, India.
1863. *WINWOOD, Rev. H. H., M.A., F.G.S. 11 Cavendish-crescent, Bath.
1888. ‡WODEHOUSE, E. R., M.P. 56 Chester-square, London, S.W.
1883. ‡Wolfenden, Samuel. Cowley Hill, St. Helens, Lancashire.
1884. ‡Womack, Frederick, Lecturer on Physics and Applied Mathematics at St. Bartholomew's Hospital. 68 Abbey-road, London, N.W.
1881. *Wood, Alfred John. 5 Cambridge-gardens, Richmond, Surrey.
1883. §Wood, Mrs. A. J. 5 Cambridge-gardens, Richmond, Surrey.
1863. *Wood, Collingwood L. Freeland, Forgandenny, N.B.
1861. *Wood, Edward T. Blackhurst, Brinscall, Chorley, Lancashire.
1883. ‡Wood, Miss Emily F. Egerton Lodge, near Bolton, Lancashire.
1875. *Wood, George William Rayner. Singleton, Manchester.
1878. ‡WOOD, Sir H. TRUEMAN, M.A. Society of Arts, John-street, Adelphi, London, W.C.
1883. *WOOD, JAMES, LL.D. Grove House, Scarisbrick-street, Southport.
1881. §Wood, John, B.A., F.R.A.S. Wharfedale College, Boston Spa, Yorkshire.
1883. *Wood, J. H. Woodbine Lodge, Scarisbrick New-road, Southport.
1886. ‡Wood, Rev. Joseph. Carpenter-road, Birmingham.
1893. §Wood, Joseph T. Hound-road, West Bridgford, Notts.
1883. ‡Wood, Mrs. Mary. Care of E. P. Sherwood, Esq., Holmes Villa, Rotherham.
1864. ‡Wood, Richard, M.D. Driffield, Yorkshire.
1890. *Wood, Robert H., M.Inst.C.E. 15 Bainbrigge-road, Headingley, Leeds.
1871. ‡Wood, Provost T. Baileyfield, Portobello, Edinburgh.
1850. ‡Wood, Rev. Walter. Elie, Fife.
1872. ‡Wood, William Robert. Carlisle House, Brighton.
*Wood, Rev. William Spicer, M.A., D.D. Higham, Rochester.
1863. *WOODALL, JOHN WOODALL, M.A., F.G.S. St. Nicholas House, Scarborough.
1884. ‡Woodbury, C. J. H. 31 Milk-street, Boston, U.S.A.
1883. ‡Woodcock, Herbert S. The Elms, Wigan.
1884. ‡Woodcock, T., M.A. 150 Cromwell-road, London, S.W.
1884. ‡Woodd, Arthur B. Woodlands, Hampstead, London, N.W.
1888. *Woodiwiss, Mrs. Alfred. Belair, Trafalgar-road, Birkdale, Southport.
1872. ‡Woodman, James. 26 Albany-villas, Hove, Sussex.
*WOODS, EDWARD, M.Inst.C.E. 6B Victoria-street, Westminster, London, S.W.
1883. ‡Woods, Dr. G. A., F.R.S.E., F.R.M.S. Carlton House, 57 Hoghton-street, Southport.
WOODS, SAMUEL. 1 Drapers'-gardens, Throgmorton-street, London, E.C.
1888. ‡Woodthorpe, Colonel. Messrs. King & Co., 45 Pall Mall, London, S.W.
1887. *WOODWARD, ARTHUR SMITH, F.L.S., F.G.S., Assistant Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
*WOODWARD, C. J., B.Sc. 97 Harborne-road, Birmingham.
1886. ‡Woodward, Harry Page, F.G.S. 129 Beaufort-street, London, S.W.

Year of Election.

1866. ‡WOODWARD, HENRY, LL.D., F.R.S., F.G.S., Keeper of the Department of Geology, British Museum (Natural History), Cromwell-road, London, S.W.
1870. ‡WOODWARD, HORACE B., F.G.S. Geological Museum, Jermyn-street London, S.W.
1884. *Woolcock, Henry. Rickerby House, St. Bees.
1881. ‡Wooler, W. A. Sadberge Hall, Darlington.
1890. §Woollcombe, Robert Lloyd, M.A., LL.D., F.I.Inst., F.S.S., M.R.I.A., F.R.S A. (Ireland). 14 Waterloo-road, Dublin.
1877. ‡Woollcombe, Surgeon-Major Robert W. 14 Acre-place, Stoke, Devonport.
1883. *Woolley, George Stephen. 69 Market-street, Manchester.
1856. ‡Woolley, Thomas Smith, jun. South Collingham, Newark.
1874. ‡Workman, Charles. Ceara, Windsor, Belfast.
1878. ‡Wormell, Richard, M.A., D.Sc. Roydon, near Ware, Hertfordshire.
1863. *Worsley, Philip J. Rodney Lodge, Clifton, Bristol.
1855. *Worthington, Rev. Alfred William, B.A. Stourbridge, Worcestershire.
Worthington, James. Sale Hall, Ashton-on-Mersey.
1856. ‡Worthy, George S. 2 Arlington-terrace, Mornington-crescent, Hampstead-road, London, N.W.
1884. ‡Wragge, Edmund. 109 Wellesley-street, Toronto, Canada.
1879. ‡Wrentmore, Francis. 34 Holland Villas-road, Kensington, London, S.W.
1883. *Wright, Rev. Arthur, M.A. Queen's College, Cambridge.
1883. *Wright, Rev. Benjamin, M.A. Sandon Rectory, Chelmsford.
1890. ‡Wright, Dr. C. J. Virginia-road, Leeds.
1871. §WRIGHT, C. R. ALDER, D.Sc., F.R.S., F.C.S., Lecturer on Chemistry in St. Mary's Hospital Medical School, Paddington, London, W.
1857. ‡WRIGHT, E. PERCEVAL, M.A., M.D., F.L.S., M.R.I.A., Professor of Botany and Director of the Museum, Dublin University. 5 Trinity College, Dublin.
1886. ‡Wright, Frederick William. 4 Full-street, Derby.
1884. ‡Wright, Harrison. Wilkes' Barré, Pennsylvania, U.S.A.
1876. ‡Wright, James. 114 John-street, Glasgow.
1865. ‡Wright, J. S. 168 Brearley-street West, Birmingham.
1884. ‡Wright, Professor R. Ramsay, M.A., B.Sc. University College, Toronto, Canada.
1831. WRIGHT, T. G., M.D. 91 Northgate, Wakefield.
1876. ‡Wright, William. 31 Queen Mary-avenue, Glasgow.
1871. ‡WRIGHTSON, THOMAS, M.Inst.C.E., F.G.S. Norton Hall, Stockton-on-Tees.
1887. ‡Wrigley, Rev. Dr., M.A., M.D., F.R.A.S. 15 Gauden-road, London, S.W.
1876. ‡WÜNSCH, EDWARD ALFRED, F.G.S. Carharrack, Scorrier, Cornwall.
1892. ‡Wyld, Norman. University Hall, Edinburgh.
1883. §Wyllie, Andrew. 1 Leicester-street, Southport.
1885. ‡Wyness, James D., M.D. 53 School-hill, Aberdeen.
1871. ‡Wynn, Mrs. Williams. Cefn, St. Asaph.
1862. ‡WYNNE, ARTHUR BEEVOR, F.G.S. Geological Survey Office, 14 Hume-street, Dublin.

1875. ‡Yabbicom, Thomas Henry. 37 White Ladies-road, Clifton, Bristol.
*Yarborough, George Cook. Camp's Mount, Doncaster.

Year of Election.

1865. ‡Yates, Edwin. Stonebury, Edgbaston, Birmingham.
1883. §Yates, James. Public Library, Leeds.
1867. ‡Yeaman, James. Dundee.
1887. ‡Yeats, Dr. Chepstow.
1884. ‡Yee, Fung. Care of R. E. C. Fittock, Esq., Shanghai, China.
1877. ‡Yonge, Rev. Duke. Puslinch, Yealmpton, Devon.
1891. ‡Yorath, Alderman T. V. Cardiff.
1884. ‡York, Frederick. 87 Lancaster-road, Notting Hill, London, W.
1891. §Young, Alfred C., F.C.S. 64 Tyrwhitt-road, St. John's, London, S.E.
1886. *Young, A. H., M.B., F.R.C.S., Professor of Anatomy in Owens College, Manchester.
1884. ‡Young, Frederick. 5 Queensberry-place, London, S.W.
1884. ‡Young, Professor George Paxton. 121 Bloor-street, Toronto, Canada.
1876. ‡Young, John, M.D., Professor of Natural History in the University of Glasgow. 38 Cecil-street, Hillhead, Glasgow.
1885. ‡Young, R. Bruce. 8 Crown-gardens, Dowanhill, Glasgow.
1886. §Young, R. Fisher. New Barnet, Herts.
1883. *Young, Sydney, D.Sc., F.R.S., F.C.S., Professor of Chemistry in University College, Bristol.
1887. ‡Young, Sydney. 29 Mark-lane, London, E.C.
1890. ‡Young, T. Graham, F.R.S.E. Westfield, West Calder, Scotland.
1868. ‡Youngs, John. Richmond Hill, Norwich.

1886. ‡Zair, George. Arden Grange, Solihull, Birmingham.
1886. ‡Zair, John. Merle Lodge, Moseley, Birmingham.

CORRESPONDING MEMBERS.

Year of Election.

1887. Professor Cleveland Abbe. Weather Bureau, Department of Agriculture, Washington, United States.
1892. Svante Arrhenius. The University, Stockholm.
1881. Professor G. F. Barker. University of Pennsylvania, Philadelphia, United States.
1887. Professor A. Bernthsen, Ph.D. Mannheim, L 7, 6A, Germany.
1892. Professor M. Bertrand. L'École des Mines, Paris.
1893. Professor Christian Bohr. 62 Bredgade, Copenhagen.
1880. Professor Ludwig Boltzmann. München.
1887. His Excellency R. Bonghi. Rome.
1887. Professor Lewis Boss. Dudley Observatory, Albany, New York, United States.
1884. Professor H. P. Bowditch, M.D. Boston, Massachusetts, United States.
1890. Professor Brentano. Maximilian-platz, München.
1893. Professor W. C. Brögger. Christiania.
1884. Professor George J. Brush. Yale College, New Haven, United States.
1887. Professor J. W. Brühl. Heidelberg.
1887. Professor G. Capellini. Royal University of Bologna.
1887. Professor J. B. Carnoy. Louvain.
1887. Dr. H. Caro. Mannheim.
1861. Dr. Carus. Leipzig.
1887. F. W. Clarke. United States Geological Survey, Washington, United States.
1855. Professor Dr. Ferdinand Cohn. The University, Breslau, Prussia.
1881. Professor Josiah P. Cooke. Harvard University, United States.
1873. Professor Guido Cora. 74 Corso Vittorio Emanuele, Turin.
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1892. Professor Dr. Gustav Fritsch. The University, Berlin.
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1884. Professor Wolcott Gibbs. Harvard University, Cambridge, Massachusetts, United States.
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